A RADIOLOGICAL STUDY OF THE RIGHT LUNG.

Thesis

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by

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The purpose of this thesis is to illustrate the author's observations on radiological investigations of the right lung both in the living body and at post-mortem, and to describe certain aspects of anatomical, clinical, pathological and radiological interest.

LIST OF CONTENTS.

HISTORICAL INTRODUCTION.

Historical Introduction.

The publication of William Harvey's 'Circulation of the Blood' in 1628 may be said to mark the beginning of our anatomical knowledge of the interrelations between the lungs and the heart. The existence of the so-called 'Lesser Circulation was recognised from that time onwards. Probably no discovery has had such far reaching results in Medicine. As Singer (1928) has put it so ably: 'The knowledge of the circulation of blood has been the basis of the whole of modern Physiology and with it of the whole of modern rational medicine'.

Harvey studied under Fabricius, of Aquapendente, who taught Anatomy in Padua during the latter half of the sixteenth century. Fabricius and his equally famous predecessor, Vesalius of Padua, described and made illustrations of the bronchial tree, the pulmonary arteries and the pulmonary veins, and recognised the division of lungs into lobes.

Although both of these great anatomists were aware of the close connection of each lung with the vessels of the heart, neither was able to free himself from the ancient theories, especially those of Aristotle and Galen.

In Galen's physiological system, the blood wa supposed to ebb to-and-fro in the veins for the purpose of ordinary nutrition. A small part of this blood was thought to penetrate to the left side of the heart through pores in the interatrial and the interventricular septa, these pores being invisible to the naked eye. In the left chambers of the heart, the blood with the 'pneuma' or vital spirit, which mixing produced a higher grade of arterial blood. The basic principle of life was this 'pneuma' which entered the body and lungs through the trachea, the one observation to some extent in accord with modern physiology. From the lung, the 'pneuma' passed through the arteria venosa (now called the pulmonary vein) to the left side of the heart.

Harvey's experiments showed that the to-and-fro ebb, postulated by Galen, did not exist, but that the blood was constantly moving in one direction and returning again to the heart. Further, the right and left sides of the heart were quite separate, and the arteries and more especially the veins (arteria venosa) were also filled with the circulating blood.

From that time, anatomists began to distinguish clearly between the pulmonary arteries and the pulmonary veins. Their descriptions are accurate in the light of modern knowledge. An illustration appearing in one of the best known of these textbooks (Cowper 1698) is reproduced here. (Fig. I). It is one among many beautiful diagrams on two large plates devoted to the anatomy of the lungs.

It is interesting to note that the terms 'arteria venosa' and 'vena arteriosa', derived from the Galenic terminology, are retained, with the alternative names 'Pulmonick vein' and 'Pulmonic artery', implying a recognition of the direction of the blood flow in these vessels. Cowper (1698) does not state in what relative positions the vessels and the bronchi lie. However, from fig. I, it is clear that the piece of lung, dissected and drawn from the anterior aspect, shows the main branches of the pulmonary artery lying close to the dorsal aspect of the bronchial tubes, the

<u>Fig. I</u>. Illustration reproduced from Cowper (1698). The text explaining this particular figure, runs as follows : ' Fig.2. Part of one of the Lobes of Lungs cutt off and a dision made according to its Length, so that a Branching of the Blood-vessels and Bronchus do appear. A-A a branch of the Pulmonik Vein or Arteria Venosa lying on that of the Bronchus.B, a Branch of the Bronchus. C, the Pulmonik Artery or Vena Arteriosa cutt transversely lying on either side of the Bronchia.'

pulmonary veins running on the opposite side of the bronchi. This conception of the relationship between artery, bronchus and vein corresponds with the present-day anatomical viewpoint (Gray, 1938).

METHODS OF STUDYING THE LUNGS.

Methods of Studying the Lungs.

A. In the living Subject -

In the living subject, four standard positions fulfil most of the requirements for the radiography of the thoracic contents. (Appleton, 1938). These are :-

(I) The postero-anterior view with the X-ray tube behind the patient and the film placed against the anterior chest wall;

(2) The right oblique view with the X-ray tube behind and to the left of the patient, and the film against the front of the chest wall, so that the rays traverse the thorax obliquely;

(3) The left oblique view in which the axis of the rays is at right angles to the previous position;

(4) The lateral or side to side view.

Tha main use of the oblique views is for a study of the various chambers of the heart, the big blood vessels and the mediastinum.

The postero-anterior and lateral views are the most valuable ones for a study of the lung fields proper. Of these two, the first is the one which is the more commonly used. In this view, the entire lung is not seen and each lung field represents only that part of the lung which lies above the shadow of the diaphragm and lateral to the mediastinum. The back-to-front axis, however, is not the best direction in which to obtain a radiograph with a view to differentiating between the bronchi and the blood vessels. These structures have an antero-posterior anatomical relationship and therefore overlap each other in this axis. In the lateral, the mass of mediastinum interferes with the study of the central portion of the lung.

When the postero-anterior view is reversedm i.e. with the X-ray tube infront of the patient and the film against the posterior chest wall, the outlines of the scapula and the shadows due to heads of ribs and the masculature of the back, becpme emphasized at the expense of the luhgs.

In the lung, the main bronchus, the primary bronchi to the lobes and their larger branches, are kept permanently open by bars and plates of cartilage. If the brinchial walls are healthy, they do not show up on the radiograph. (Kerley, 1936). When they are filled with secretions, they can often be seen as linear striations, closely resembling pulmonary arteries.

The pulmonary arteries contain blood, which is relatively opaque and thus appear as a series of linear shadows radiating from the root of the luhg. As will be shown later, it is not always easy to distinguish between a blood vessel and a bronchus filled with secretion.

B. The removed lung -

Very interesting and instructive radiographs can be made of the removed luhg, and many problems of anatomical, clinical, radiological and pathological interest can be investigated by this method.

Lungs obtained either from the post-mortem or antomy dissecting room may be used. In contrast to the radiography of the lung in the living subject, lateral radiographs of the removed lungs obviously present no difficulty and every part of the lung is seen on the plate.

Further, each lung can be treated in different ways in order to render the bronchial, the pulmonary arterial or the pulmonary venous trees radio-opaque.

Specimens of the right lung only were used in the present investigation because the right lung has an extra fissure which produces an extra lobe, and its anatomical make-up is therefore more complicated than that of the left lung. All the structures mentioned in the paragraph above, have been investigated.

S U M M A R Y.

(1) A brief historical review is presented of the interrelationship between the heart and the lungs.

(2) Methods of studying the lungs are outlined and the advantages and disadvantages of the various procedures are discussed.

(3) Attention is drawn to the methods and value of studying lungs removed from the body.

THE BRONCHIAL TREE.

INTRODUCTION.

There is a great difference of opinion among anatomists as regards the mode of division of bronchi. Aeby (1880) held the view that the primary bronchi are direct continuations of the two main bronchi, into which the trachea subdivides, and that from each main stem, lateral branches are given off in a monopodial manner. Aeby represented the Continental viewpoint. Ewart (1889) on the other hand, believed in dichotomy, and thus differs from Aeby. d'Hatdvillier (1895) opposed the theory of dichotomy, supporting Aeby in this respect, but differing from him in the manner in which the bronchi arise from the main stem. Jutesen (1900) believed in a modified dichotomy and used the term 'sympodial! He maintained that one branch becomes much more highly developed than the other, similar to the mode of division in plants. Flint (1907) believed tha the branching of the main branches is monopodial but that subsequent division may be either monopodial or dichotomous. Hė (1887) studied the development of the lungs in the human embryo.

With Aeby he agreed that the mode of division of the main bronchi was monopodial. The lateral branches, according to him, came off in a dichotomous manner. Miller (1938) is in accord with Aeby in that the division of the main series is monopodial, but he finds that the mode of division of the smaller branches is a 'mixed monopody and dichotomy'. Twining (1938) states :

'Thr branches are rarely symmetrical as to the size of the resulting bronchi. Nearly always one of the pair is larger than the other. This asymmetry has raised difficulties for the anatomists for it is not easy to determine whether the larger divisions, which may be nearly in a straight line, represent a continuous stem bronchus or not. The result of difference of opinion on this point has been that the bronchial tree is differently described in Continental and in English literature. The former follows Aeby, who described the branching as monopodial .... while English writers adopt a nomenclature based generally on Ewart's classical work.

Ewart described the branching as dichotomous and assailed the previously held theories of Aeby. The discrepancy is of more interest to anatomists than radiologists .... "

EXPERIMENTAL METHODS, RESULTS AND DISCUSSION.

Experiment I.

The modern means of demonstrating the branching of the bronchi in the living subject is radiography after lipiodol injection. The lipiodol covers the lining of the bronchi and renders them sufficiently opaque for visualisation on the radiograph.

Studies were made of radiographs after lipiodol injection. The observations are recorded below and illustrated in Figs. 2. and 3.

Fig. 2. Normal Bronchogram (postero-anterir view), showing the bronchial tree of the right lung.

Fig. 3. Normal bronchogram (lateral view), showing the bronchial tree of the right lung.
(same case as fig. 2).

Results and discussions.

From the living subject.

On the bronchogram (Figs. 2 & 3), the branches of the right main bronchus are clearly visible. It is for example possible to see the ep-arterial bronchus with its apical, axillary and pectoral branches, the right middle lobe bronchus with its sterno-cardiac and its superficial mammary cardiac branches, and the right main bronchus with its posterior horizontal (first dorsal) lesser posterior horizontal (second dorsal), posterior basal, axillary basal, anterior basal and retrocardiac branches.

The mode of division of the larger branches can be clearly made out. The branching suggests monopody. As far as the smaller bronchi are concerned, the mode of division also appears to be monopodial in the main, but dichotomous division is also apparent.

There is little need to stress the important part bronchography plays in the diagnosis of chest lesions. It is common knowledge that bronchiectasis can be diagnosed with absolute certainty after lipiodol injection of the bronchial tree. (Figs. 4 & 5). Not only can the diagnosis be made with the fullest confidence, but t is also possible to determine which bronchi are mainly affected, for example 'posterior basal branches of the lower lobe bronchus'. This knowledge is of the greatest value to the thoracic surgeon.

Bronchial occlusion can also be diagnosed by bronchography. It does not matter whether the cause is in the lumen (e.g. foreign body), in the wall (e.g. bronchial carcinoma) or outside the wall (e.g. aneurysm, tumours, etc.).

In short, the application of the knowledge of bronchography in the living subject is so obvious and well-known that there is no need for further discussion here.

Fig. 4. Bronchogram (postero-anterior view) showing bilateral basal bronchiectasis.

Fig. 5. Bronchogram (lateral view) showing the accurate localisation of the disease to certain bronchi. (same case as fig. 4).

Experimental methods 2 .

The study of the bronchial tree in the living subject was supplemented by the radiography of removed lungs in which the bronchi were injected with contrast material.

Description of the technique of injecting bronchi :

Materials used : (a) a 10 cc. Higginson's syringe,
(b) Barium sulphate suspension,
(c) Flat receptacle for lung,
(d) Cottonwool.

Method: The lung is placed in the receptacle with the hilum upwards. The nozzle of the syringe, filled with the opaque material, is then introduced into the bronchus selected. The opaque material is then injected very slowly and without force, until the bronchus can hold no more. During this procedure, the mouth of the bronchus is approximated to the nozzle of the syringe with the thumb and fore-finger of the left hand. This is to prevent any external leakage. The opening is then plugged with cottonwool. Radiographic studies are then made with the lung in the A.P. and lateral positions at a distance of 60 inches.

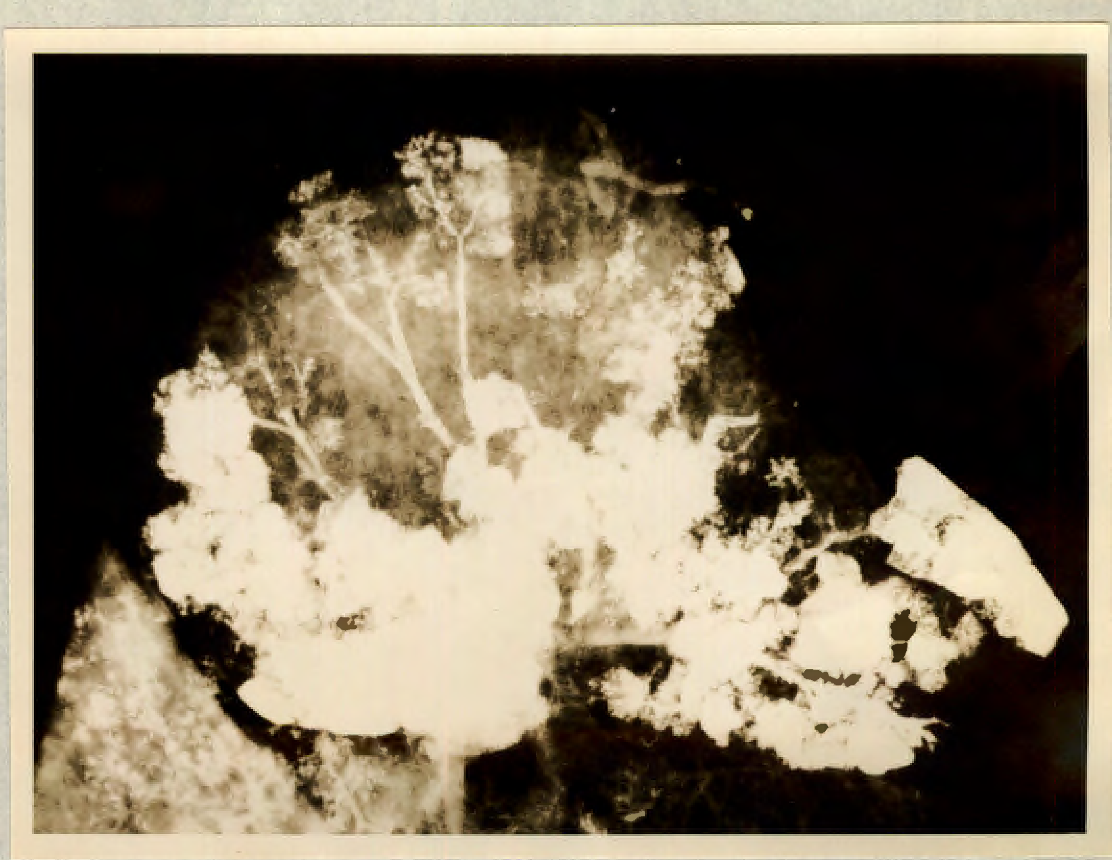
Some of the lungs used in this experiment were preserved in formalin for a few weeks and had become hard and slightly contracted. In spite of this, the injection of the barium sulphate suspension showed up the bronchial tree quite well.

Results and discussions.

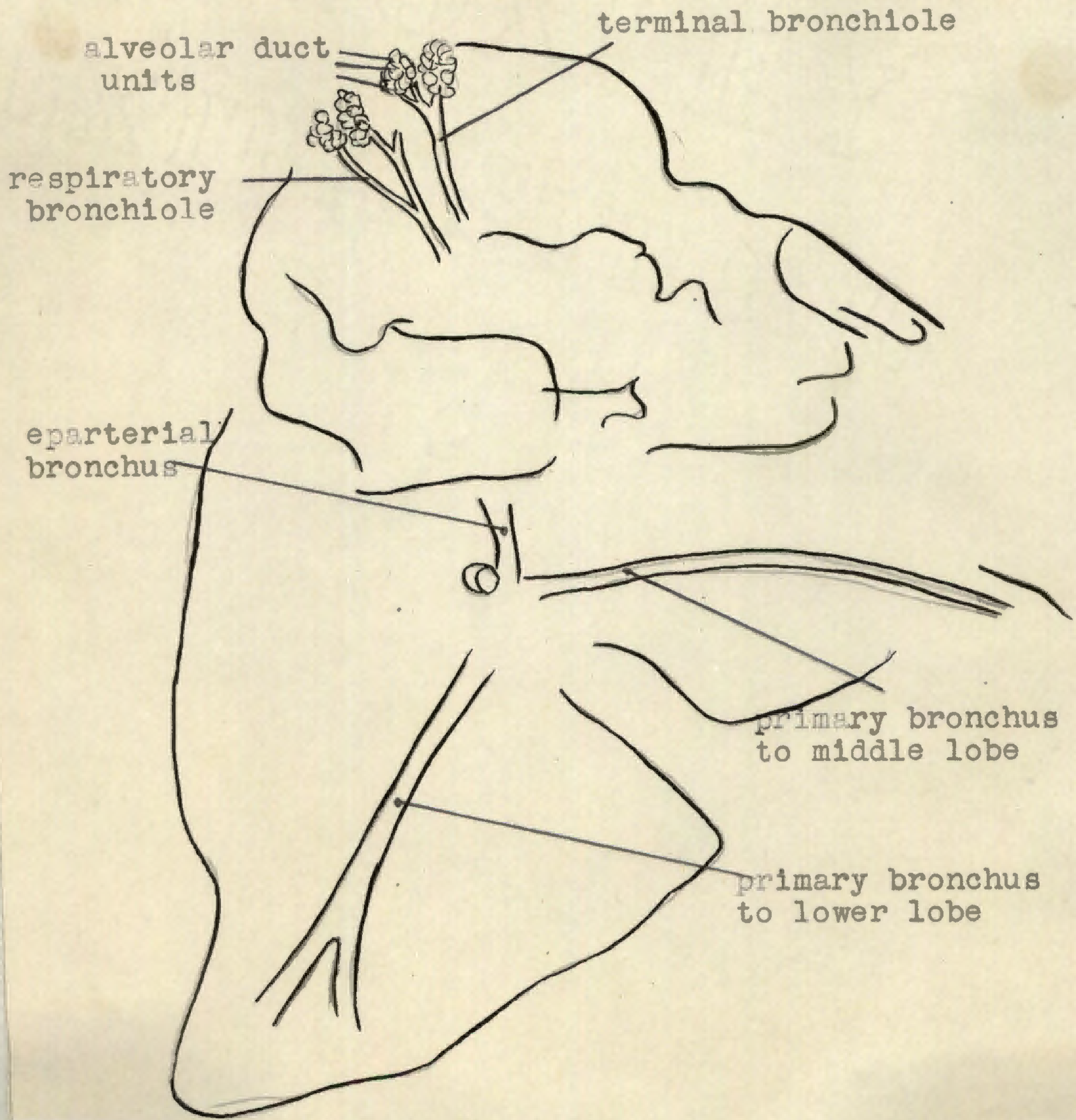
Fig. 6. is a radiograph of a lung treated in the manner described. It shows many of the finer anatomical points concerning the bronchi and their subdivision. It becomes clear that each bronchus divides in a monopodial manner, that is, the branches spring from the sides of the bronchi and the linge of the main bronchus is continued straight on into the lower lobe. The origins of the branches, into which the barium did not penetrate, are seen along the bronchi in the form of little dark rings. The mode of division, as shown by the radiograph of the removed lung corresponds with the findings from the bronchogram in the previous experiment. One would like to point out that the division of the larger bronchi is practically invariably monopodial but dichotomous division does occur in the smaller branches.

It may be pointed out also that this monopodial origin of the branches of the bronchial tree is in accord with the embryological observation that secondary lung buds during development appear

Fig. 6. Lateral radiograph of a removed lung in which the bronchi of the three lobes have been injected with contrast fluid.
The large white patches are pools of contrast fluid that has escaped through alveoli ruptured during the injection.



Enlarged view of the upper lobe of the lung in fig. 6.


terminal bronchiole
alveolar duct
units
respiratory
bronchiole
eparterial
bronchus
primary bronchus
to middle lobe
primary bronchus
to lower lobe

Key to Fig. 6.

laterally off the main tube (Edwards, 1938).

The findings here, that is regarding the mode of division of the bronchi, are in agreement with Aeby and contrary to the views of Ewart. As indicated earlier, there is, however, exceptions to the rule in the smaller branches, where mixed monopody and dichotomy can be observed.

Furthermore, one cannot agree with Twining 'that the discrepancy is of more interest to the anatomist than the radiologist.' Surely, a wrong conception of the anatomical make-up will be detrimental to the advancement of radiologic interpretation, as the latter is based on the former. In a subsequent section, I shall come back to this aspect and attempt to show how exact knowledge of the mode of division of the bronchi and the arteries may be helpful in the interpretation of certain X-ray appearances on an ordinary straight radiograph.

Experimental methods 3.

In order to demonstrate the terminal subdivision of the bronchi, the barium suspension was first injected into all three the primary bronchi. Then a second injection was made into the primary upper lobe or ep-arterial bronchus with rather more force. The result was that some of the lobules and alveolar duct units became outlined in this lobe. But further, the barium burst through the air sacs over certain areas and ran together into pools filling up the interstitial tissue of the lung (see large white patches in Fig. 6.).

Results and Discussion.

Fig. 6 is a radiograph of a lung prepared in this way. The subdivision of the main bronchus into primary bronchi, secondary bronchi, bronchioles, terminal bronchioles and respiratory bronchioles, can be seen. To my knowledge, no previous attempt has succeeded in showing such fine anatomical detail by radiography. Most of the finer points, determined by laborious methods of dissection, modelling and histology, can be shown by the injection of the bronchial tree with contrast material and subsequent radiography.

Each respiratory bronchiole gives rise to several alveolar ducts and each alveolar duct opens out into air sacs or atria, from the sides of which very numerous terminal alveoli bulge out. The '<u>respiratory lobule</u>' is the branching system resulting from one respiratory bronchiole. (<u>Fig. 6.</u>)

The diameter of a respiratory bronchiole varies between 0.5 and 0.2 mm., and in the barium injected bronchial tree (Fig. 6), these are the terminal fine lines.

A still smaller unit is demonstrated by a metal cast illustrated in a Histology Textbook (Maximow, 1930). The 23 times enlargement of the cast indicates that an 'alveolar duct unit' measures some 4 to 5 mm. in diameter; several such units together make up the 'lobule'. Measurements on the actual radiograph confirm that the small units are really alveolar duct units. As stated, several alveolar duct units make up the respiratory lobule.

SUMMARY.

(1) The bronchial tree of the right lung has been investigated by means of radiographs taken after lipiodol injections in the living subject.

(2) The applications of this study in cases of bronchiectasis and of bronchial occlusion due to various causes is discussed.

(3) The bronchial tree has also been studied by means of radiographs of lungs removed from the body both at autopsy and in the anatomy dissecting room.

(4) Methods are described for rendering the bronchial tree in these lungs radio-opaque.

(5) From these studies on both the removed lungs and the living subject, it is concluded that the bronchi divide chiefly in a monopodial manner. This finding is in agreement with the work of Aeby and contrary to that of Ewart.

(6) It is maintained, in disagreement with Twining, that exact anatomical knowledge of the bronchial tree is of importance in radiological interpretation.

(7) A method of injecting the terminal subdivisions of the bronchi and demonstrating them radiologically is described for the first time.

(8) The detailed anatomy shown in this way confirms the findings of previous histological studies.

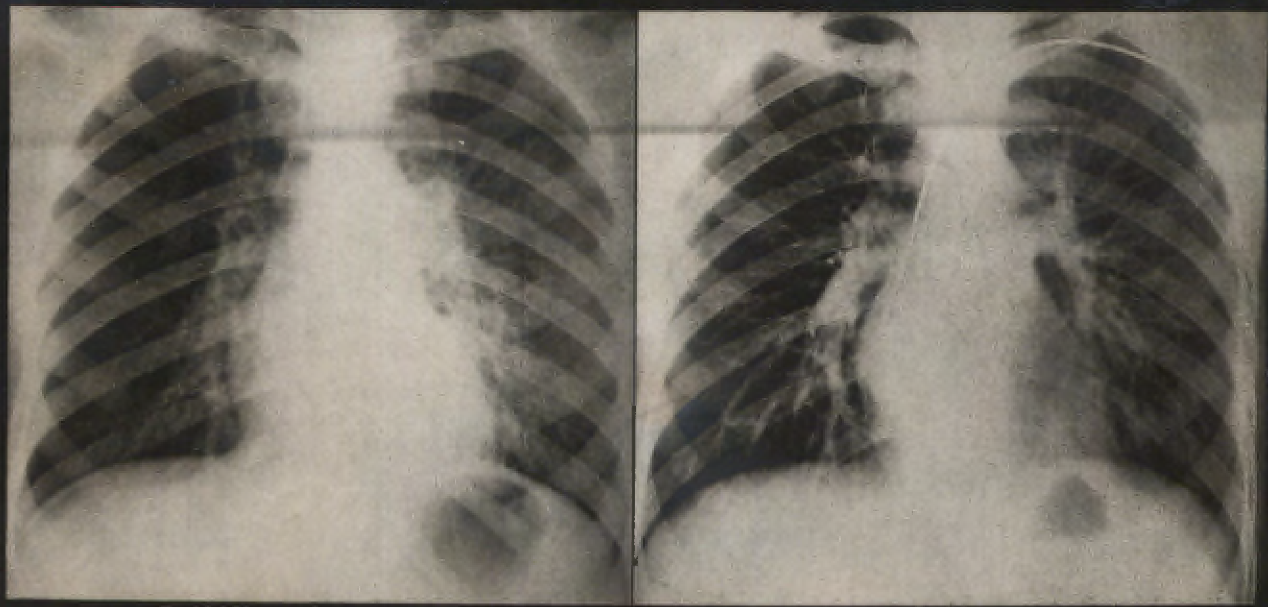
THE PULMONARY ARTERIAL TREE.

Introduction.

Moniz (1933) has injected the pulmonary arterial tree in the living subject with a contrast medium, sodium iodide solution. He passed a catheter into the superior vena cava through a vein in the left arm. The pulmonary arterial tree became very much intensified on the radiograph. This is shown in Fig. 7.

This work of Moniz has shed considerable light on the part played by the pulmonary arterial tree on the radiograph of the chest. It becomes clear that the root shadows and many of the linear ramifications in the pulmonary field are in part due to vascular ramifications.

With regard to the respective sizes of the bronchi and pulmonary arteries, Miller (1937), the famous lung anatomist, makes the following statement : 'At first the artery and bronchus have nearly the same diameter, but the artery diminishes more rapidly in size than the bronchus, so that by the time it reaches the lobule it is about one quarter or one fifth the



(a) (b)

FIG. 85. (a) Normal lung before angiopneumography. (b) Angiopneumogram. Catheter passed through vein of left arm into superior vena cava. Injection of sodium iodide. Pulmonary arteries and their branches strongly intensified by the opaque injection. (*Egas Moniz.*)

<u>Fig. 7.</u> Angiopneumogram. Catheter passed through vein of left arm into superior vena cava and sodium iodide injected. Pulmonary arterial tree markedly accentuated.

From Moniz (1933).

size of the ductus alveolaris'. This statement is accompanied by a diagram of the primary lobule showingthe respective sizes of the alveolar duct and pulmonary artery. This sketch has been incorporated in 'A Textbook of X-ray Diagnosis' (1938) by British Authors, also in Morris's Human Anatomy and is generally accepted as a classical and correct description. The same diagram is reproduced in this thesis as a photostat (Fig. 8).

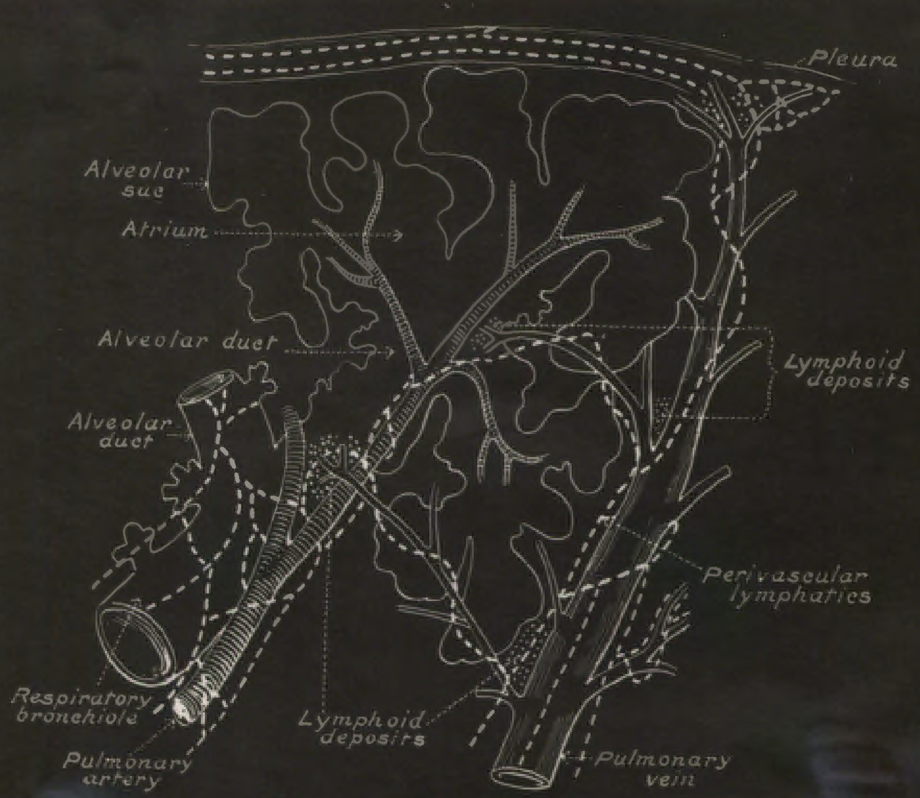


FIG. 171.—Diagram: Primary lobule of lung. The course of the lymphatics is indicated by a broken line. Lymphoid deposits dotted. (After *W. S. Miller.*) The respiratory bronchiole divides into two alveolar ducts bearing atria, each of which has a number of alveolar sacs, on the periphery of which are the alveoli. A branch of the pulmonary artery goes to each atrium and is distributed to the alveolar sacs. The pulmonary vein is situated between the primary lobules.

<u>Fig. 8.</u> Primary lobule of the lung. The respiratory bronchiole divides into two alveolar ducts bearing atria each of which has a number of alveolar sacs, on the periphery of which are the alveoli. A branch of the pulmonary artery goes to each atrium and is distributed to the alveolar sacs. The pulmonary vein is situated between the primary lobules.

From Miller (1937)

<u>Note the small arterial diameter as compared with the respiratory bronchiole</u>.

Experimental Methods.

Injection of barium into Pulmonary Arterial Tree.

Lungs which are fixed outside the body are useless for the purpose of showing the vascular trees in injection experiments, because both pulmonary arteries and pulmonary veins become firmly contracted, and do not allow the penetration of contrast fluid. It is necessary therefore to une fresh post-mortem material and the X-ray photography must be done preferably within a few hours as decomposition is rapid.

The method of Injection.

The pulmonary arteries are injected in exactly the same manner as the bronchial tree (see description in previous section). The requirements are also

(a) a syringe,

(b) a flat receptacle for the lung,

(c) barium sulphate suspension,

(d) cottonwool.

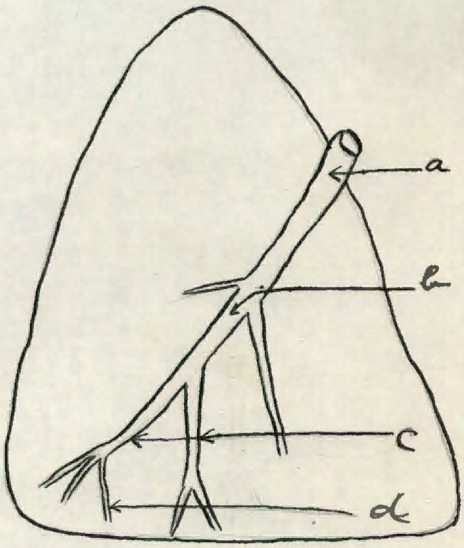
It is very important that NO FORCE is used during the injection, and the contrast material must be allowed to run into the pulmonary arteries. This is very important in view of the fact that one aims at the complete absence of any material distension of the arterial tree with consequent increase in the width of the lumen.

Fig. 9. is the lateral radiograph of a right lung in which the lower lobe branch of the pulmonary artery has been injected with a barium sulphate suspension. In parts of the lobe, the pulmonary artery can be traced as far as its distribution to the alveolar duct unit. In addition to the pulmonary artery outlined by contrast fluid, there can be seen two long pieces of metal with rounded lower ends; one is straight and lies om the lower lobe bronchus; the other spirally twisted one is in the lower lobe branch of the pulmonary vein.

Fig. 10 is a lateral radiograph of a right lung in which the upper, middle and lower lobe bronchi have been injected with

Fig. 9. Lateral radiograph of a removed lung. The lower lobe pulmonary artery has been injected with opaque solution. The straight rod is in the lower lobe bronchus and the rod with the spirally twisted mid-portion is in the pulmonary vein.
This illustrates the intra-pulmonary anatomical relationship of these structures.

Fig. IO. Formalin fixed lung. The bronchi of all the three lobes have been injected with contrast fluid. The letters a-d indicate the points at which the bronchi were measured. (see Table I)

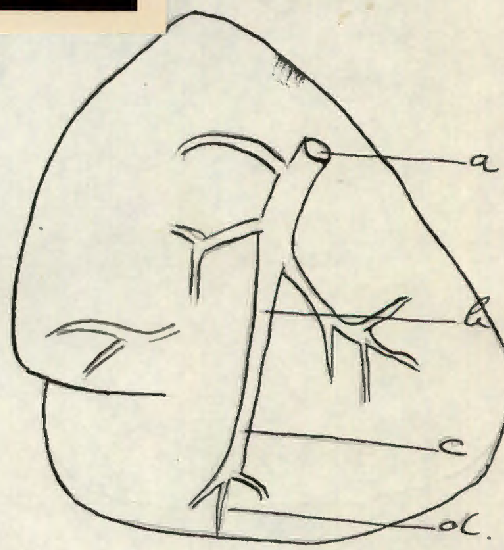


Key to fig. IO.

barium suspension. The lung has been fixed in formalin.

Fig. 11 is a lateral radiograph of a right ling with the pulmonary arteries to the lower lobe and also the middle lobe bronchus, have been injected with contrast fluid.

Fig. II. Fresh lung removed at autopsy. The middle lobe bronchus and the lower lobe pulmonary artery have been injected. The letters a-d indicate the points at which the artery was measured.(Table I).



Key to fig. II.

Results.

(1) The intrapulmonary anatomical relationship is clearly demonstrated by fig. 9. From before backwards there are the pulmonary vein, the bronchus and then the pulmonary artery.

Fig. 9 confirms the findings in Fig. 1, a dissection illustration made and published two and a half centuries ago.

(2) Fig. 11 shows the middle lobe bronchus as well as the lower lobe pulmonary arterial tree in the same lung. It is obvious that the branches of the bronchus visualised, and the branches of the lower lobe pulmonary arteries are constantly equal in size to one another.

(3) The diameters of the bronchi and of the branches of the pulmonary artery were made in corresponding positions of the radiographs of Figs. 10 and 11. The results are shown in Table I.

	Bronchus	Pulmonary artery.
(a) Near root of lung	6 m.m.	6.4 m.m.
(b) Midpoint between root and surface	3.6 m.m.	3.8 m.m.
(c) Three quarters way to surface	1.9 m.m.	1.8. m.m.
(d) Near surface, i.e. respiratory bronchiole.	0.5. m.m.	0.5 m.m.

Table I. Measurements of Bronchi and Arteries in corresponding positions.

In this comparison of Figs. 10 and 11, it may be objected that the lung in Fig. 10 had been fixed in formalin, while the lung in Fig. 11 was a fresh specimen. This objection is not valid as bronchi are unaffected by formalin fixation. Compare for example, the bronchi of the formalin fixed lung (Fig. 10) with the bronchial tree in the living subject (fig. 2). To prove this point beyond any doubt, the bronchi of a few freshly removed lungs were injected with contrast material and the radiographs compared with Fig. 10. There was no perceptible difference in the diameters of the bronchi of the fresh and formalin fixed lungs.

From these results, <u>it is obvious that the artery does</u> decrease as rapidly in size as Miller suggested, but that it remains throughout practically the same size as the bronchus. If anything, the artery shows a slightly wider diameter quite as far as the small subdivision corresponding with the respiratory bronchiole.

(4) Mode of division of pulmonary arteries.

The arteries subdivide quite differently from the bronchi. The larger tributaries conform to dichotomous division and it can be clearly seen on Fig. 11 how each moderately sized twig subdivides into two equally sized branches. Smaller branches appear laterally off the larger vessels. Ramification is much more apparent in the case of the arterial tree.

Discussion.

(1) Intrapulmonary anatomical relationship.

Present experiments whowed results in agreement with accepted views, which were already described by Cowper in 1698.

(2) Relative sizes of bronchi and arteries.

An obvious discrepancy exists between the findings obtained here and those of Miller (1937). The explanation of this difference probably lies in the fact that in lungs studied histologically, the vessels have shrunk in the process of fixation, while the bronchi, with cartilage in their walls, have retained their dimensions. Thus an erroneous impression of the relative sizes has arisen. There can be no doubt that the arteries keep practically the same size as far as the alveolar duct, and do not decrease so rapidly in size in comparison with the bronchi, as Miller suggested.

(3) Difference in the mode of division of the bronchi and the arteries.

In a previous section, I have dealt with the mode of division of the bronchi, and have come to the conclusion that in the main, the mode of division is monopodial. On the other hand, it has been shown that the arterial division is dichotomous. There may be a difference of opinion as to how exactly every individual bronchial or arterial branch subdivides. There can, however, be no question about the observations that there is a definite difference between bronchial and arterial subdivision. This is clearly demonstrated in Fig. 11.

With the constant improvement in radiographic technique, more and more accurate anatomical knowledge of the part X-rayed is required for a clear appreciation of the complicated radiographic shadows. It therefore becomes important to have a very clear understanding of points like mode of division of the bronchi and the arteries, intrapulmonary anatomical relationships and the respective diameters of the bronchi and the pulmonary arteries.

Normal bronchi as a rule cast no shadow on the X-ray plate.

Kerley (1936) states: 'it is obvious that if the walls of the trachea, the thickest of the whole bronchial tree, cannot be visualised, there is little chance of smaller bronchi casting an opacity unless they are literally stuffed with secretion.'

It can therefore be accepted that normal bronchi cast no shadow on the X-ray plate. Bronchi filled with secretion, or bronchi, whose walls are thickened from disease, DO cast shadows. <u>Thus bronchi that are visible, must be regarded as being diseased</u>. Recognition of bronchi under such circumstances may thus afford a clue to the early recognition of pathology.

It is of the utmost importance therefore to decide whether a given linear shadow on a chest radiograph is a bronchus or a bloodvessel. <u>If one can definitely determine such a linear shadow to be a bronchus, and not a bloodvessel, then disease of the bronchi, must be present</u>. Unfortunately, it is often extremely difficult to distinguish bronchial shadows from vascular ramifications. Correct anatomical knowledge obviously is very necessary in order to make the distinction.

It was with this in mind that this effort was made to establish the difference between bronchial and arterial division. As previously stated, I am convinced that such a difference does exist and enables a distinction between bronchi and bloodvessels to be made. This is one of the reasons why the criticism is levelled against Twining for the statement 'that the mode of division is of more interest to anatomists than radiologists.'

An accurate knowledge of the direction in which the pulmonary arteries run, as shown by Moniz, is of importance in other instances. As Twining (1938) so ably put it : 'If observation of the vascular trunk shadows is combined with this observation of the position of the interlobar fissures a still clearer conception of the atelctasis and compensatory emphysema is obtained. The trunk shadows must for this purpose be traced back to their points of emergence from the hilum, from which they radiate. These radiant points are constant for each lobe and can be memorised when the anatomy of the bronchi has been learned, for the vessels run with the bronchi through the lung parenchyma. It will be found that the trunk shadows of the atelectatic lobe are lost in the obscurity of this lobem while the trunk shadows visible in the translucent part of the lung can be identified as belonging to the other lobes. If the atelectasis is a partial one affecting only a wedge-shaped area of the one lobe, the trunk shadows of the unaffected portion of the lobe can still be identified.'

All these points show the importance of accurate knowledge of the detailed anatomy of the bronchi and pulmonary bloodvessels.

SUMMARY

(1) Attention is drawn to the study of the pulmonary arterial tree in the living subject by Moniz.

(2) Methods of injecting contrast media into the arterial tree of the removed lung are described.

(3) Lungs studied radiographically after this preparation show the intrapulmonary anatomical relationship to be as demonstrated two and a half centuries ago by Cowper.

(4) The diameters of the bronchi and the pulmonary artery branches were measured at corresponding distances from their commencement. It was found that at all points, right down to the finest divisions visualised, the bronchi and pulmonary arteries are more or less equal in size to one another. This refutes Miller's suggestion that the arteries diminish in size much more rapidly than the bronchi, and that the smallest divisions of the arteries are only one fourth to one fifth of the diameter of the bronchi.

(5) The mode of division of the pulmonary arteries is described. It is dichotomous in type.

(6) Attention is drawn to the difference in the modes of division of arteries (dichotomous) and bronchi (monopodial), as revealed by the present studies.

(7) It is pointed out that the anatomical features described in the present work are of the utmost importance in the early recognition of pathology in the bronchi, and in the interpretation of straight radiographs. Bronchi that are visible on a straight radiograph are pathological. Hence, if a shadow can be identified as bronchial and not arterial, then pathology must exist in those bronchi. The anatomical features described anable the distinction to be made.

THE PULMONARY VENOUS TREE.

Experimental Methods.

It was found that the lungs from bodies preserved for anatomy dissection, were suitable for investigating the pulmonary venous tree.

In the preparation of the cadaver, the formalin solution is run into the femoral artery under considerable pressure. After death, neither the aortic nor the mitral valves are functioning, and the formalin solution penetrates into the left side of the heart and from there in a reversed manner into the lungs via the pulmonary veins. With the exception of the lungs, all the other organs of the body become injected from the arterial side. After a few days, when the formalin has everywhere soaked into the tissues, a second injection is made into the femoral artery, this time with a solution of starch and vermilion for the purpose of giving the arteries a reddish colour and thus facilitating dissection. In the case of the lungs, the pulmonary veins receive the starch and vermilion. The colouring matter vermilion is a mercuric salt, mercury sulphide, thus providing an excellent contrast material. Thus X-ray studies of the venous tree in the lung can be made.

The right lung seen in Figs. 12 & 13 was a specimen obtained from the anatomy dissecting room and illustrates the pulmonary venous tree. The pieces of wire will again be referred to in the next section ("The lobes and fissures of the right lung.")

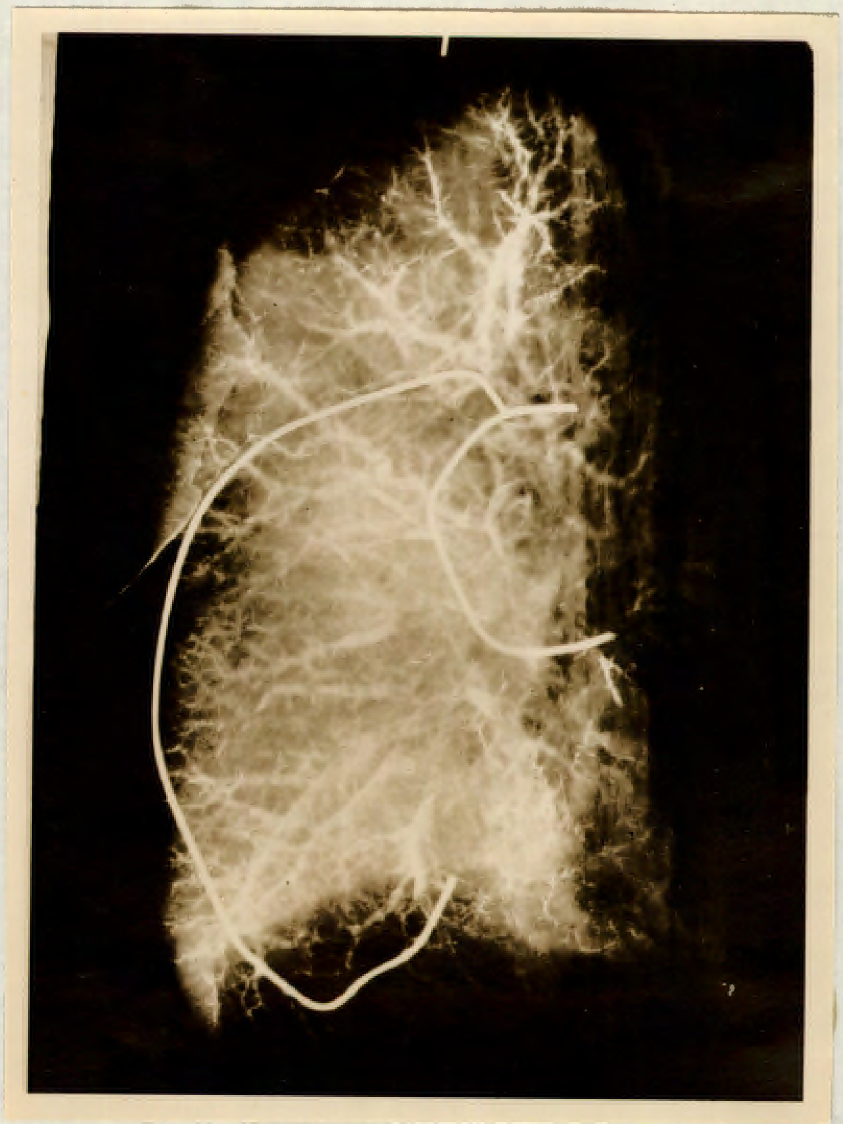


Fig. I2. Postero-anterior radiograph of a right lung with the pulmonary vein injected with contrast material. The pieces of wire are in the oblique fissure.

Fig. I3. Lateral radiograph of a right lung with the pulmonary vein injected with contrast material. The pieces of wire are in the oblique fissure.

Results.

The pulmonary venous tree, shown up by the vermilion, can be followed quite as far as in the case of the pulmonary arterial tree in Fig. 11, and this inspite of the previous fixation by formalin.

The mode of division of the pulmonary venous tree is similar to the mode of division of the pulmonary arterial tree (described in previous section).

Discussion.

The difference in behaviour of the lung when formalin fixed inside and outside the body has to my knowledge never been discussed in the pathological literature.

When the lung is preserved INSIDE the body by formalin solution injection through the vessels, the latter do not seen to contract because the second injection of starch and vermilion, four or five days later, penetrates quite easily (Figs. 12 and 13). OUTSIDE THE BODY, the lung reacts quite differently. If a lung is removed from the body and fixed by formalin solution, even for a few days, it is impossible any longer to inject contrast material into the pulmonary artery and pulmonary vein. This was tested on several fresh lungs removed post-mortem, and it makes no difference whether such lungs are immersed in formalin or whether the formalin is injected directly into the pulmonary veins.

An explanation of this phenomenon is not easy to give. But it is suggested that the explanation lies in the fact that the lungs remain inside the airtight pleural cavities on the one hand and are exposed to atmospheric pressure on the other hand.

Such an interpretation, which has been arrived at through the radiological study of the lung, may throw some light on the problem of <u>IN-SITU FIXATION</u> (or Intra-vitam fixation) of tissues. The above-mentioned anatomical method of body preservation seems to have shown the way towards the understanding of the more delicate method of tissue fixation, although no connection between the two has ever been claimed. The in-situ method of fixation is generally recognised to be far superior to the more ordinary methods of fixation. Apart from the question of preventing the earliest onset of decomposition, it may be that the exposure to atmospheric pressure is an important factor.

S U M M A R Y

(1) The lungs from bodies preserved by formalin and injected with starch and vermilion for anatomy dissection were found to be suitable for radiological investigation of the pulmonary venous tree without further preparation.

(2) If lungs are removed from the body and fixed in formalin for a few days, it is impossible to inject the pulmonary vascular trees.

(3) The explanation probably lies in the fact that the lung preserved inside the body is protected from atmospheric pressure.

(4) The investigation suggests that this feature may help to explain why the i n - s i t u method of fixation of tissues is the most satisfactory.

THE FISSURES AND LOBES.

of

THE RIGHT LUNG.

Investigations were carried out in the living subject and in removed lungs in the previous sections.

(I) <u>Observations on the fissures of the right lung</u>.

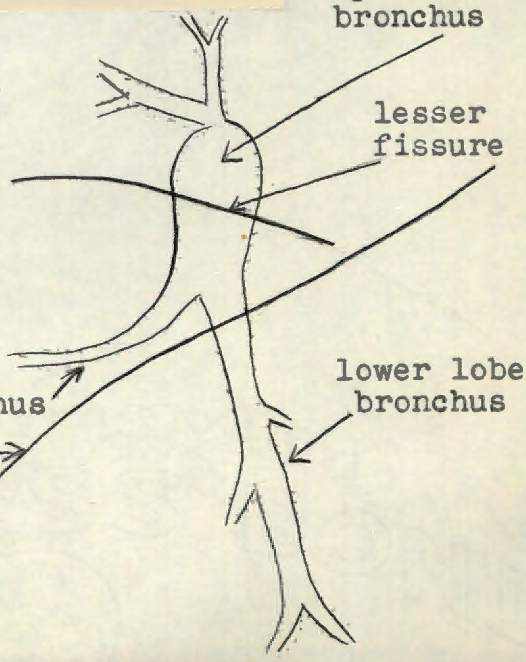
Antero-posterior and lateral skiagrams of normal chests were studied.

Removed lungs were also studied.

Figs. 12 & 13 (already referred to in the section on the pulmonary venous tree) prepresent lateral and postero-anterior skiagrams of a right lung with the pulmonary vein injected with contrast material and pieces of wire placed in the oblique fissure.

Fig. 14 is the lateral radiograph of a right lung removed at autopsy and preserved by immersion in formalin solution.

Fig. 14. Lateral radiograph of a lung removed post-mortem and preserved by immersion in formalin solution. The features illustrated are shown in the key.



Key to fig. 14.

Results.

From a consideration of figs. 12, 13 & 14 it becomes clear that in the right lung there is a deep oblique fissure which penetrates its substance to within a short distance from the hilum and which forms the upper limit of the lower lobe. In the anterior part of the right lung there is a second cleft called the horizontal or lesser interlobar fissure. This demarcates a wedge-shaped portion at the lower end of the upper lobe, thus giving the right lung three lobes.

The two fissures and the three lobes of a right lung are clearly seen in Fig. 14. Furthermore, in this latter figure, translucent bronchial tubes can be traced to some extent.

The Main Interlobar Fissure.

In the anatomy dissecting room specimen (figs. 12 & 13), the oblique or main interlobar fissure was outlined by means of curved pieces of wire placed on the surface of the lung and in the deepest portion of the fissure near the hilum.

These radiographs show the oblique fissure is more likely to be visible in the lateral view than the postero-anterior view. In the latter position (Fig. 12) the rays pass at an angle to the plane of the fissure. In the lateral view (Fig. 13) the rays pass almost parallel to the plane of the fissure.

Thus fig. 15, a diagram of a chest in the postero-anterior projection, does not show up the main interlobar fissure, whereas fig. 16, the diagram of the chest in the lateral projection, clearly shows the oblique fissure.

A line drawn from the vertebral end of the third rib obliquely downwards to a point opposite the lateral part of the sixth costal cartilage, may be regarded as representing the position of the main interlobar fissure on the lateral X-ray photograph. (Twining, 1938).

Fig. 16 shows the oblique fissure to be more or less in the position described.

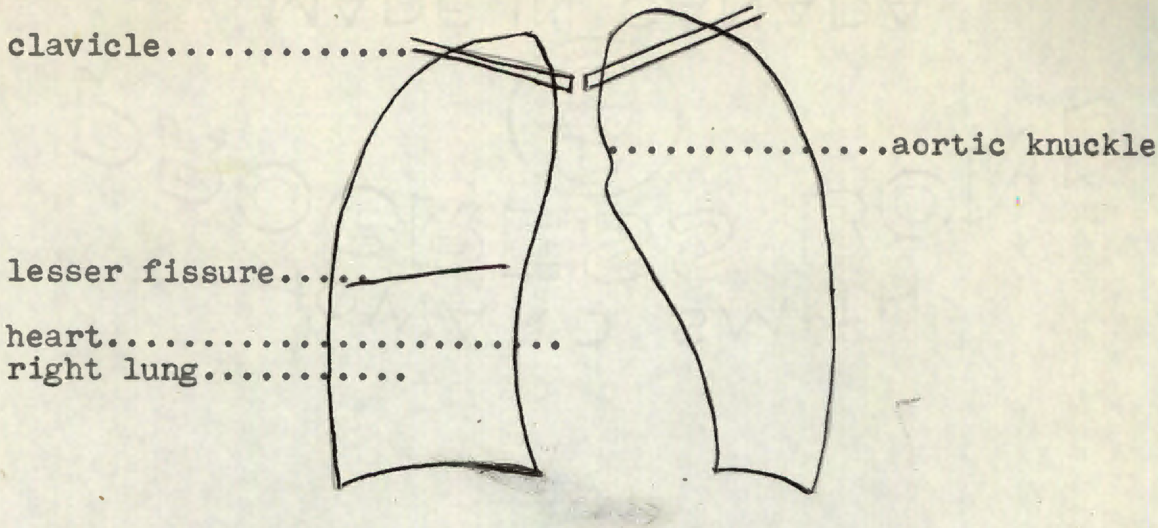


Fig. I5. Postero-anterior view (diagram) of chest showing lesser fissure.

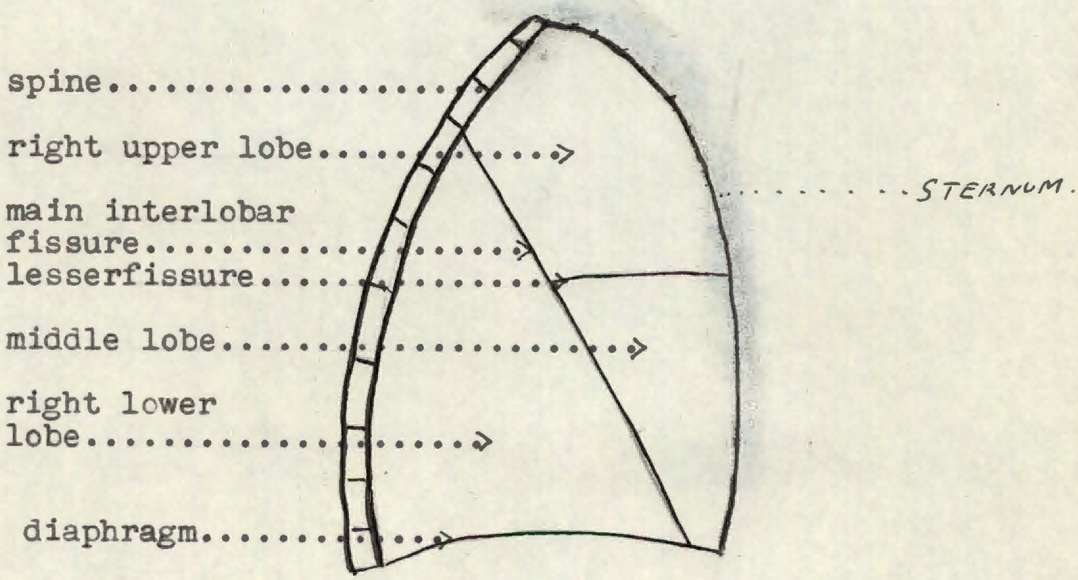


Fig. 16. Lateral view (diagram) of chest showing the oblique and the main fissure.

<u>The Lesser Interlobar Fissure.</u>

The lesser interlobar fissure lies in a horizontal plane. Therefore postero-anterior and lateral views are both suitable for showing up this fissure, since the rays pass parallel to the plane of the lesser fissure in both views.

The lesser fissure starts from the main fissure where the latter crosses the posterior axillary line and ends anteriorly at the level of the fourth costal cartilage (Twining, 1938).

Figs. 15 & 16 show the lesser fissure to be more or less in the position described. As stated above, the lesser or horizontal fissure is clearly visible on both the postero-anterior and the lateral views. On the postero-anterior view, it shows as a thin hairline in the right third or fourth interspace.

Detailed observations on the lesser interlobar fissure.

The postero-anterior views of 400 normal chests were investigated with special reference to the lesser interlobar fissure.

160 of the subjects were males and 240 were females. Only adult patients were investigated.

The observations made are recorded in Table II below.

The 'angle x' included in Table II, is the angle, the lesser fissure makes with the vertical. It is ,easured as follows (Fig. 17):- A line A-B is drawn joining the lowermost points of convenient ribs, e.g. the 6th rib on either side. A line C-D is then drawn perpendicular to A-B, preferably in a position which facilitates direct measurement of the angle x.

In those cases in which the fissure was slightly convex, the shortest distance between the two ends was regarded, for the sake of ease, as the position of the fissure.

The angle x was studied only in the postero-anterior skiagrams, because it was found that in many instances, the fissure was visible in this view but not on the lateral view.

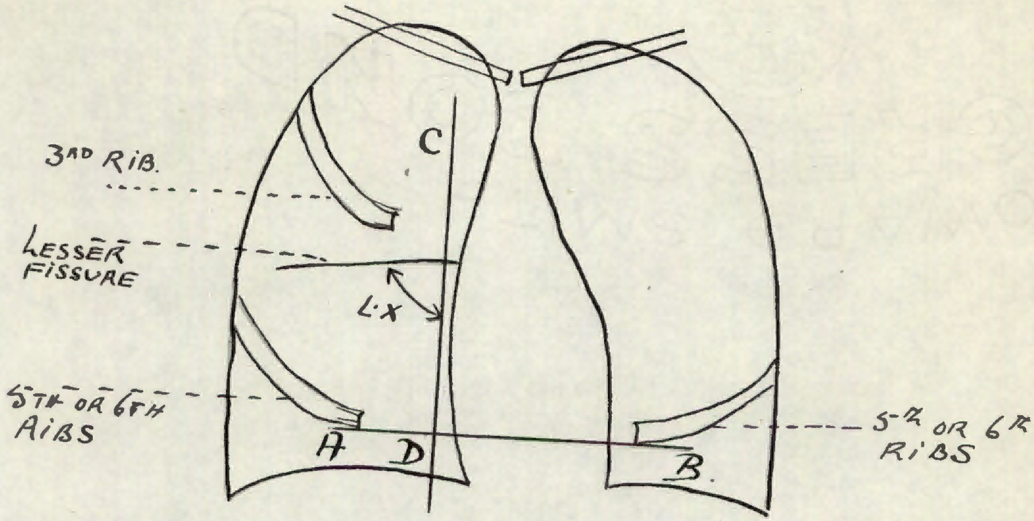


Fig. I7. To show how angle x is measured.

A-B is a line joining the lowermost aspects of the 6th rib on either side.

C-D is a perpendicular line dropped on A-B in such a position as to facilitate direct measurement of angle x.

Number of chests studied		400
Lesser fissure visible in		250
" "	single "	200
" "	double "	50
" "	in third interspace in	126
" "	" fourth " "	124
" "	straight in	130
" "	convex upwards in	120
" "	" downwards in	0
Angle x (see accompanying graph)		80 - 105 degrees.

Table II. Observations on the lesser fissure in 400 normal chests (postero-anterior views only.)

From the figures in Table II, the following features of the lesser interlobar fissure may be described :

(1) The lesser fissure is visible in 62.5% of cases.

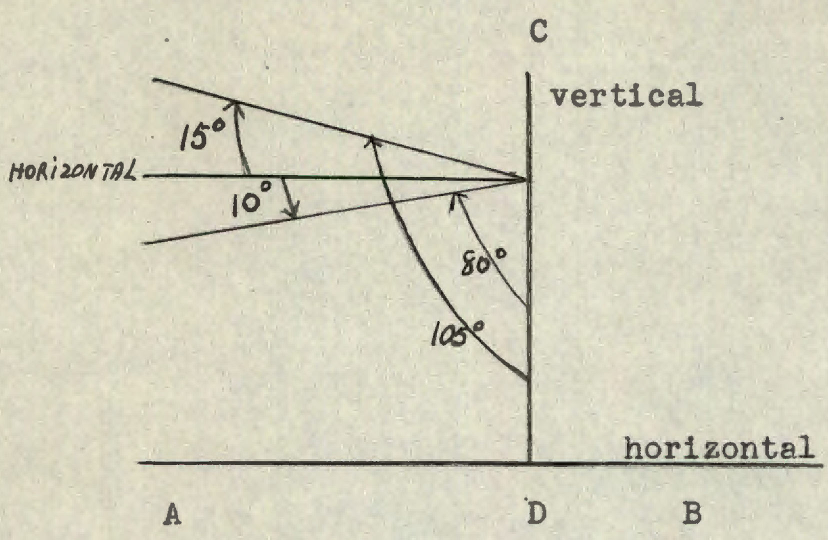
(2) 80% of the fissures seen are single. In the remaining 20% a double line is present.

(3) Approximately 50% of the fissures are seen in the 3rd right interspace and 50% are seen in the 4th right interspace.

(4) The fissure is straight in 52% of instances and convex upwards in the remaining 48%. It is never convex downwards.

(5) The angle the lesser fissure makes with the vertical varies between 80 degrees and 105 degrees, i.e. the fissure

depressed I0 degrees below the horizontal, or elevated I5 degrees above the horizontal in normal lungs.



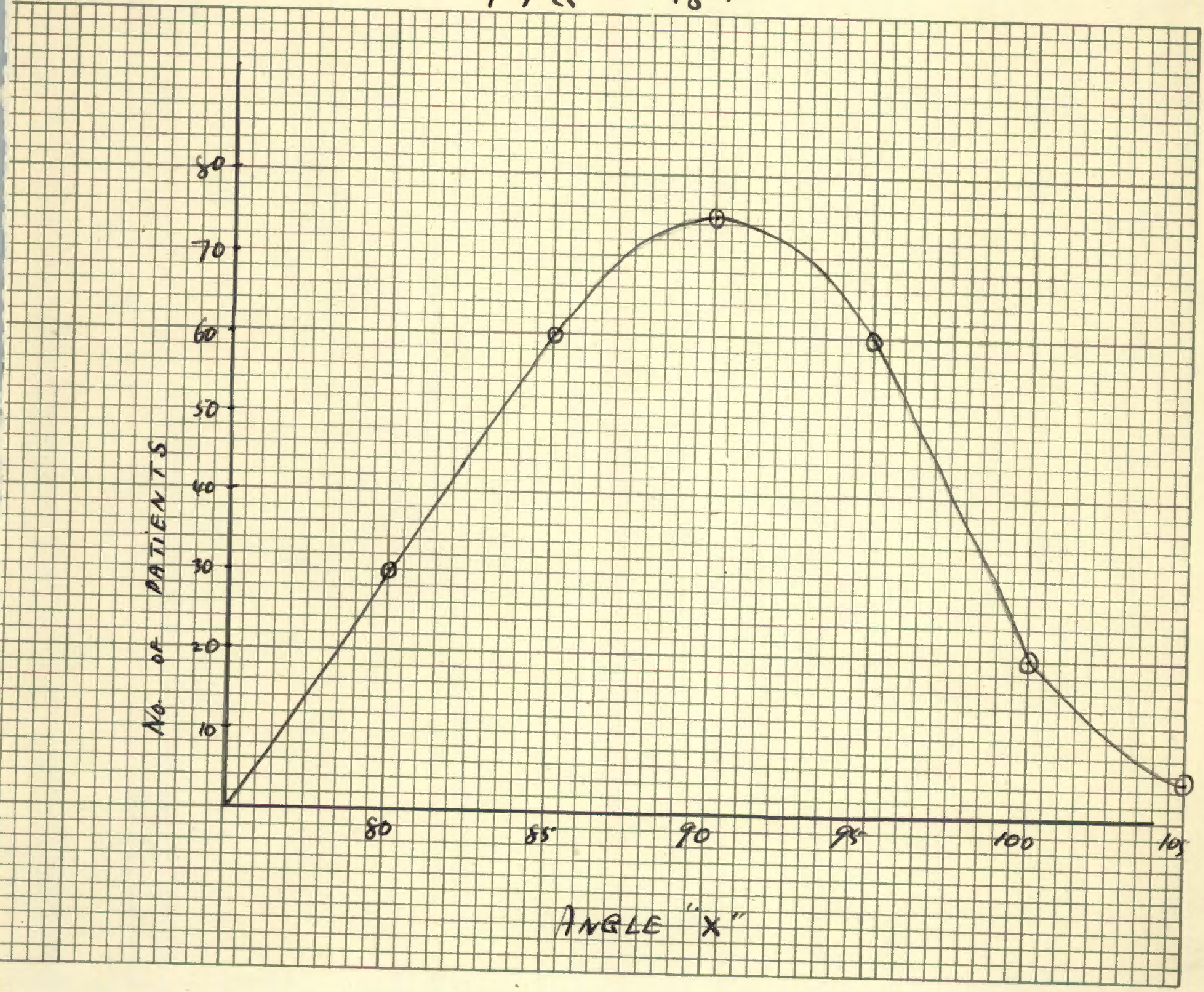
The lower aspect of the anterior end of the third rib on the right side was taken as a guide to the position of the lesser fissure at its medial end.

It was found that the lesser fissure was never further away from this landmark than I2 mm. (obviously the nearest portion of the fissure to the rib mentioned, which was usually found to be the medial end of the fissure). Actually, in the majority of films examined, the distance varied between 8 and I0 mm. This observation can be added as

(6) to the above list of features.

(7) A graph accompanies this description showing clearly the curve when the number of cases is charted against the angle of inclination (x) (FIG. 18).

FIG 18.



(7) A graph accompanies this description showing clearly the curve when the number of cases is charted against the angle of inclination (x) (Fig. 18).

Additional observations.

During the course of the investigation of the 400 cases described above, observations were made on the fissure of the Azygos Vein and on the fissure of the True Azygos Lobe.

The most important features of these are discussed below.

a. The Azygos Vein Lobe Fissure.

The fissure of this anomalous lobe, if present, is seen as a thin hair line in the right upper quadrant (Fig. 19). It extends from the hilar region obliquely upwards in a variable direction. It usually, however, crosses the clavicle in its middle third. The base of this fissure, i.e. the part in contact with the hilar region, is usually much thicker than the rest and is often pear-shaped or triangular.

(Twining 1938 and Kerley 1936). The line may be straight or convex. When it is convex, the convexity is outwards. (Own observation, as far as one is aware).

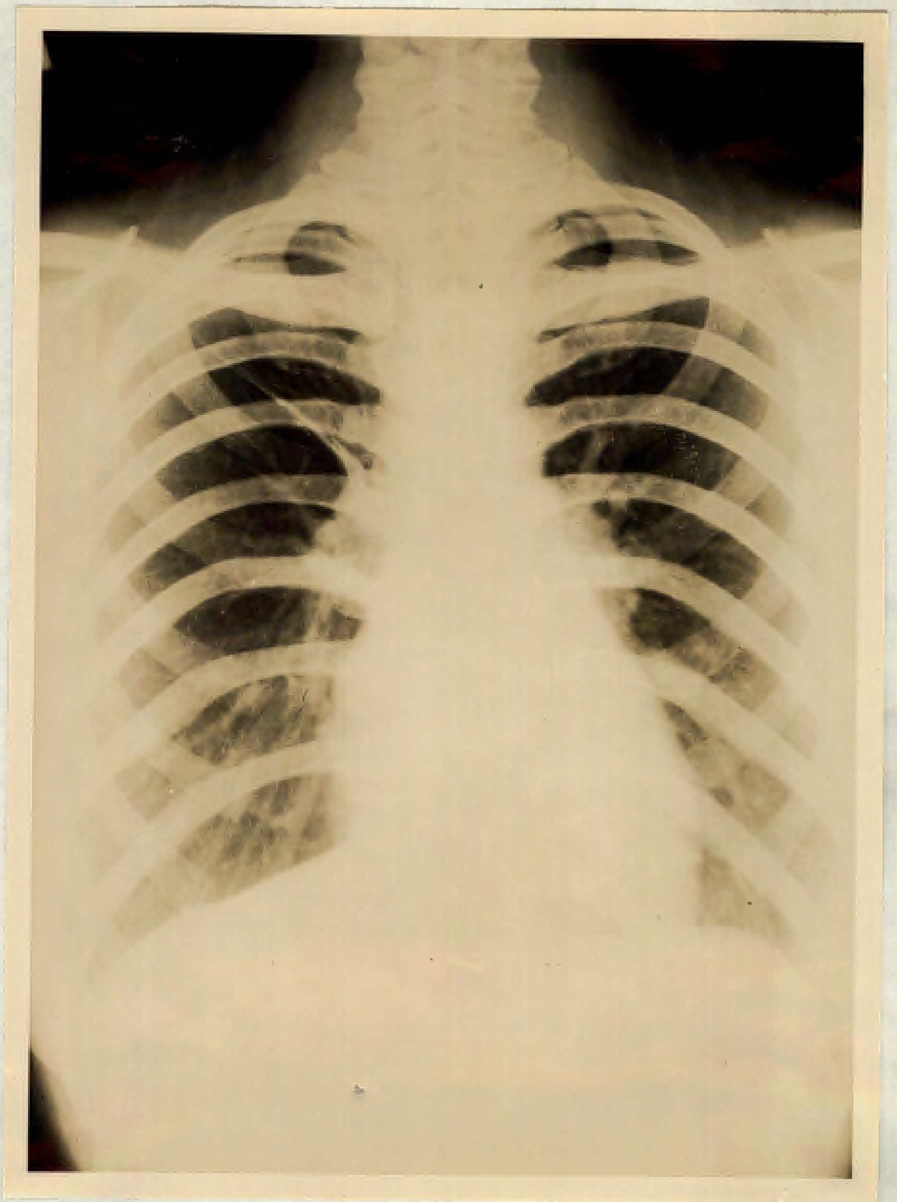


Fig. I9. Postero-anterior radiograph of a chest showing an Azygos Vein Lobe Fissure, at the upper zone.

b. The True Azygos Lobe Fissure.

This fissure was seen in 40 of the 400 normal chests investigated, i.e. an incidence of 10%. Richards (1933) found it in 10 of 2000 chests roentgenograms, i.e. an incidence of a half percent. Twining (1938) observed it in 8% of 500 unselected roentgenograms. The results of the present investigation correspond closely with Twining's findings and are at variance with Richards'.

The fissure of the True Azygos Lobe appears on the roentgenogram as a fine line which is either straight or convex laterally. It runs obliquely outwards from the right hilar region to end about the middle of the right dome of the diaphragm as a triangular peak (Fig. 20).

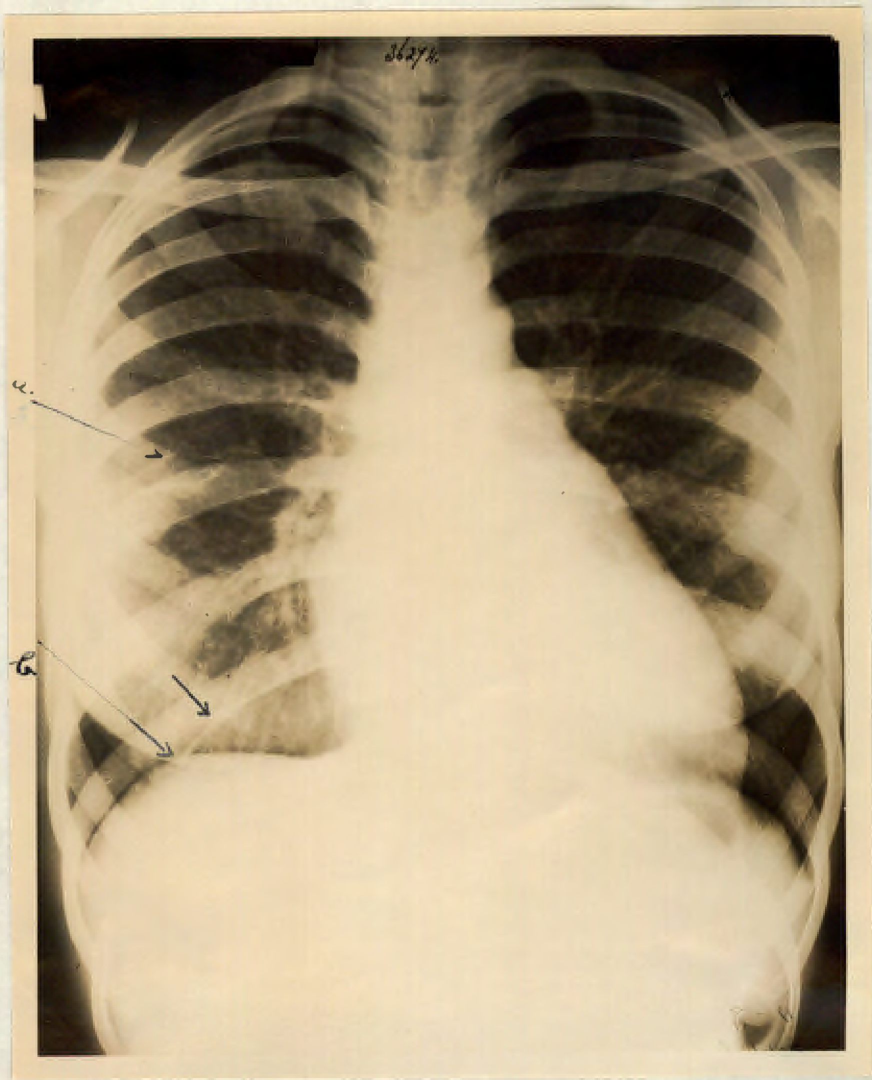


Fig. 20. Postero-anterior radiograph: (a) distorted lesser fissure (as is seen often with fibrosis) and (b) A True Azygos Lobe Fissure at the right base showing the typical triangular peaking of the diaphragm.

Observations pertaining to a study of the lesser interlobar fissure in various pathological conditions have been incorporated into the section of the discussion entitled 'The lesser interlobar fissure in abnormal conditions.'

DISCUSSION.

I propose to confirm my remarks mainly to the lesser interlobar fissure and to indicate briefly some of the conditions in which a knowledge of the fissure may be useful in the interpretation of chest skiagrams.

Before considering the conditions which can affect the fissure, I wish to discuss briefly the differentiation of the lesser fissure from other causes of a 'hair-line' in the right pulmonary field.

Differential Diagnosis of a 'hairline' in the right pulmonary field.

The following must be distinguished from the lesser fissure.

1. An Azygos Vein Lobe Fissure.
2. A True Azygos Lobe Fissure.
3. A Pleural Adhesion.
4. Knutson's Sheath and
5. A Linear Area of Atelectasis.

1. <u>The Azygos Vein Lobe Fissure.</u>

This has been described above. It is differentiated by the following points :

(a) The lesser fissure may be present in addition to the above fissure.

(b) The base of the azygos vein lobe fissure, as described above, is always thicker than the rest of the fissure. The base of the lesser fissure does not show this thickening.

(c) If the azygos vein lobe fissure is convex, the direction of the convexity serves to distinguish it from the lesser fissure. The present investigation shows that the convexity of the lesser fissure is <u>never downwards</u>. The convexity of the Azygos vein lobe fissure is usually downwards (or outwards).

2. <u>A True Azygos Lobe Fissure</u>.

The characteristic 'peaking' of the diaphragm by this fissure (Fig. 20) is present so constantly, that it may be regarded as a feature on which the differentiation from a displaced fissure can be based.

Further, careful search for the lesser fissure in the normal position sometimes show the latter to be present.

3. A Pleural Adhesion.

It is only in rare instances that an adhesion, e.g. to the diaphragm, produces a picture simulating a depressed fissure. The typical diaphragmatic peaking and the fact that the direction of the adhesion is usually very vertical, usually affords a clue to the correct diagnosis.

4. Knutson's Sheath.

Kerley (1936) stated: 'The shadow accompanying the second rib also shows thickening (referring to passive hyperaemia). It was previously thought that the shadow was pleural in origin, but Knutson has shown that it is produced by a sheath of connective tissue containing the superior intercostal artery and vein and a large branch of the first thoracic nerve. The clarity of this shadow in Mitral Stenosis is certainly due to swelling of the vessels in Knutson's sheath, and in many doubtful cases of Mitral Stenosis, its thickened appearance may be of diagnostic value.'

From the foregoing, one would therefore expect to find an abnormal cardiovascular shadow, when a Knutson's sheath is present. Difficulty might, however, arise in distinguishing this from an elevated lesser fissure, especially as thickening of the lesser fissure is also very common in Mitral Stenosis. The position of the latter fissure is however as a rule in the 3rd or 4th interspace and not in the region of the second rib. Further, it is also extremely likely that in Mitral disease, the lesser fissure will also be thickened from transudation into it, and cast an additional shadow. Thus two lines will probably be present.

In the author's own experience, the finding of a Knutson's sheath is extremely rare. The radiograph of the lung of one patient with Mitral Stenosis, showed a line accompanying the second rib and presenting all the features of a Knutson's sheath. At autopsy, this line was found to be a pleural adhesion.

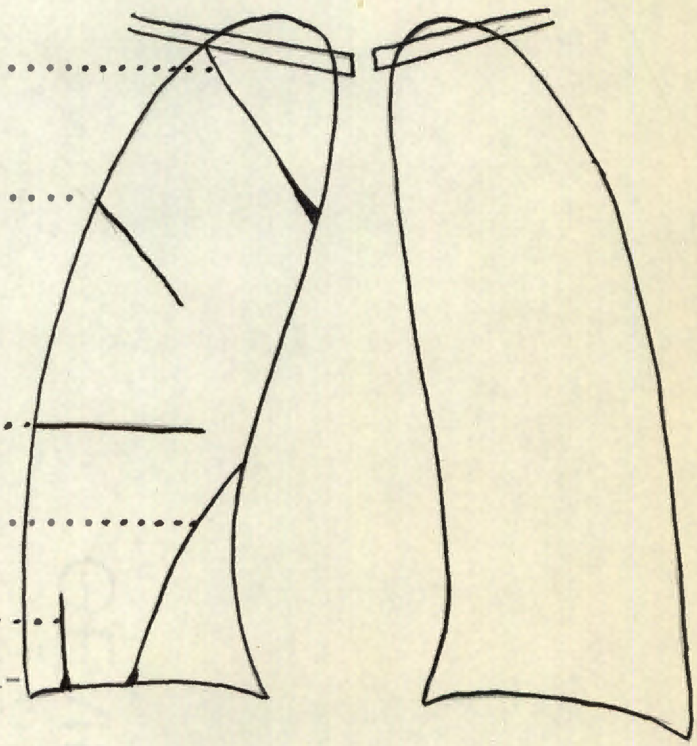
5. <u>Linear or segmental atelectasis.</u>

Very often fine transverse lines are visible at the bases more or less parallel with the diaphragm. These lines are due to segmental atelectasis, and are frequently mistaken for a depressed lesser fissure or pleural adhesions.

These lines are common in cases with prolonged elevation of the diaphragm, and can therefore be expected in patients suffering from intra-abdominal swellings. Many other causes are mentioned in the literature (Twining, 1938), e.g. acute abdominal conditions, fractured ribs etc. I have personally seen typical linear atelectasis at the right base of a patient who inhaled a foreign body. This transverse area of atelectasis was actually associated with slight elevation of the diaphragm. It promptly disappeared after patient coughed up the foreign body.

Distinction between a displaced fissure and linear atelectasis is usually not difficult. A depressed lesser fissure is usually displaced downwards with its lateral aspect much lower than its medial aspect.

A linear area of atelectasis is usually parallel with the dome of the diaphragm, and the medial aspect is much on the same horizontal level as the lateral aspect.



Azygos Vein Lobe Fissure
(note thick base)

Knutson's sheath
(note position)

Lesser fissure

True Azygos Lobe fissure
(note triangular peaking)

Typical diaphragmatic adhesion (note peaking of diaphragm and vertical inclination of the 'line').

Diagram showing the typical appearances of structures mentioned.

THE LESSER INTERLOBAR FISSURE IN ABNORMAL CONDITIONS.

A study of the lesser interlobar fissure is of tremendous importance in the accurate diagnosis of many pathological conditions.

Table III is a summary of the changed that may take place in the lesser interlobar fissure, and indicates the conditions in which diagnosis is assisted by such a study.

A detailed discussion of the problem follows.

(I) Thickening of the Fissure.

A. Marked Thickening.

Interlobar effusion.

B. Slight Thickening.

Idiopathic pleurisy.

Pneumonia

Lung abscess

Pulmonary Tuberculosis

Cardiac disease

(II) The Fissure as a Line of Demarcation.

Upper lobe consolidation

Middle lobe consolidation

Lower lobe consolidation.

(continued overleaf):

(III) <u>Displacements of the Lesser Fissure</u>.

A. <u>Marked Displacement</u>.

1. <u>Atelectasis</u>

Upper lobe atelectasis

Middle lobe atelectasis

Lower lobe atelectasis

2. <u>Fibrosis</u>

3. <u>Space-occupying lesions</u>

a. <u>Fluid conditions</u>

Encysted effusion

Synpneumonic effusion.

b. <u>Solid conditions.</u>

Lung tumours, benign and malignant.

Lung abscesses.

Hydatids.

B. <u>Slight Displacement</u>.

1. Bronchiectasis.

2. Emphysema.

<u>Table III.</u> <u>A Summary of the conditions in which a Study of the Lesser Interlobar Fissure is of Diagnostic Importance.</u>

(I) Thickening of the Lesser Interlobar Fissure.

Thickening of the fissure may be either marked or slight.

A. Marked Thickening.

The commonest cause of marked thickening of the lesser Interlobar fissure is Interlobar Effusion. (Fig. 21 & 22). The diagnosis of this condition may be very simple or very difficult. On the postero-anterior view, a shadow of varying density may be seen in line with the fissure, and in many instances, the division of the fissure to enclose the opacity can be seen. In some cases a rounded opacity may be seen on the radiograph (Kerley, 1936). This has to be distinguished from other causes of a rounded opacity, in a lung field, e.g. hydatid, primary neoplasm, secondary neoplasm etc. The lateral view usually serves to differentiate an interlobar effusion from other causes of a rounded opacity, v.i.z.

(a) There is the association with the fissure, (b) the shadow is fusiform with pointed ends, lying along the course of the

Fig. 21. Postero-anterior radiograph showing marked thickening of the lesser interlobar fissure due to fluid.

Fig. 22. Lateral view of fig. 21, showing the thickened lesser interlobar fissure.

fissure.

In cases where an interlobar effusion complicates a pneumonia, the diagnosis is not always easy. In the portion of a consolidated lobe in contact with the fissure becomes denser than the rest of the fissure, then an interlobar effusion may be suspected. Downwards bulging of the fissure in such instances, clinches the diagnosis.

Such an interlobar effusion may rupture into a bronchus, and a fluid level then becomes visible. The position of the fluid level differentiates it from a middle lobe abscess, as in the former, the fluid level is higher in the chest than with middle lobe abscess (Fig. 23 & 24).

B. Slight Thickening.

This can be secondary to a great variety of conditions. It may occur along with most intrathoracic inflammatory conditions, e.g.idiopathic pleurisy, pneumonia, lung abscess and tuberculosis.

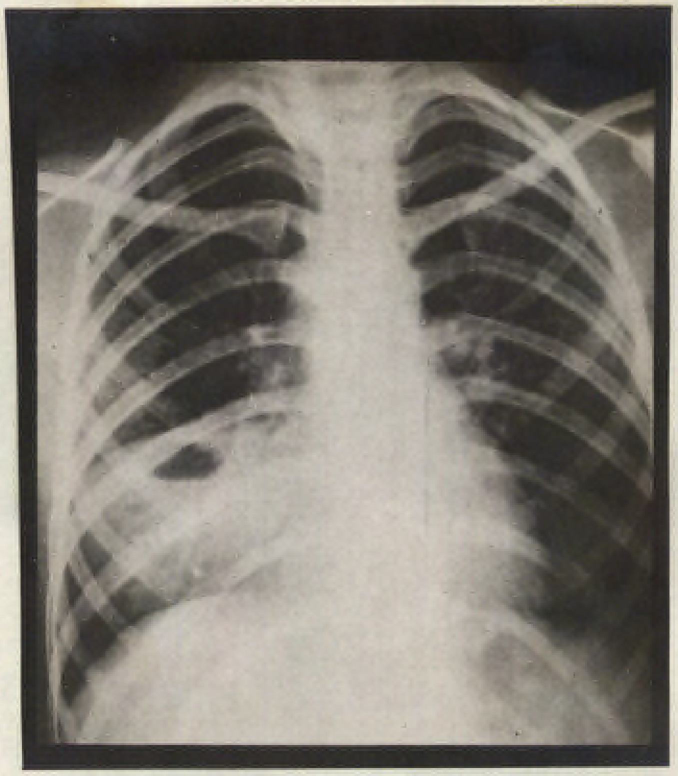


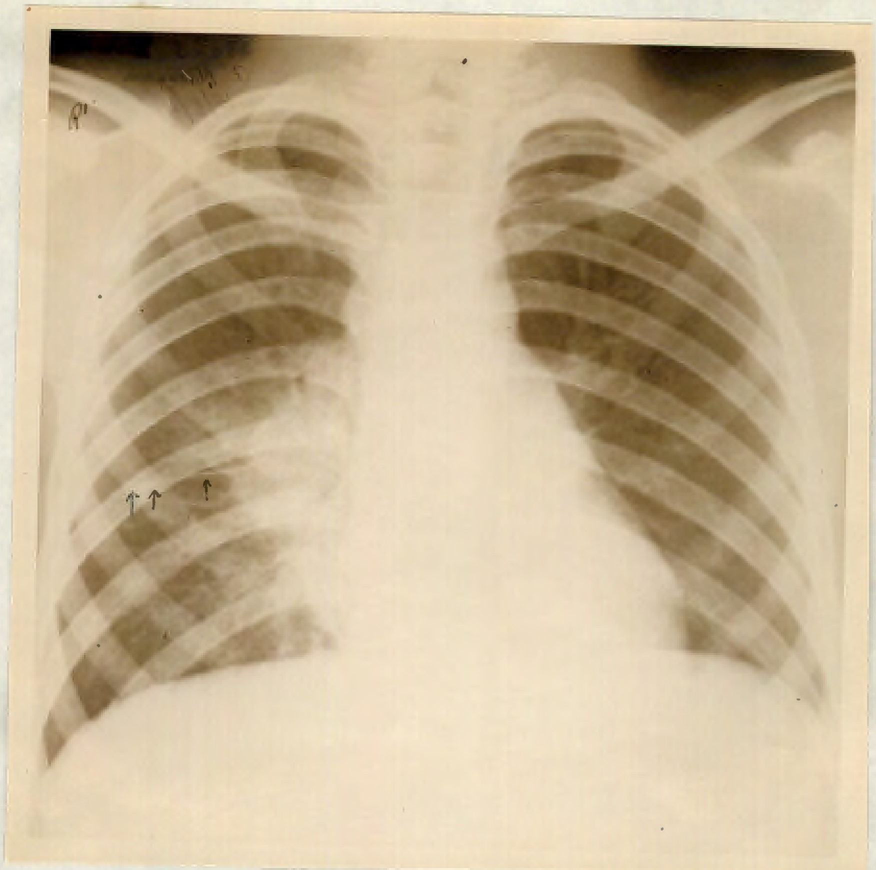
Fig. 23. Postero-anterior view of a chest showing an abscess cavity in a consolidated right middle lobe. Note the 'wedge-shaped' area of basal consolidation outlined above by the horizontal fissure.

From "A Text-book of X-ray Diagnosis" by British Authors.

Fig. 24. Lateral view of fig. 23, showing a cavity in a consolidated middle lobe. The position of the fluid level differentiates it from an interlobar empyema with broncho-pleural fistula.

From "A Text-book of X-ray Diagnosis" by British Authors.

Thickening of the fissure, plus enlarged bronchial glands may be the sole indication of Koch's Infection in childhood, and appropriate lateral views should be done in all children with a thickened fissure. The object of this is to determine whether or not bronchial glands are enlarged. These are often not visible on the postero-anterior view, but clearly visible on the lateral view. In routine examination of children with slight pyrexia and some constitutional disturbance, the author of this thesis has often been struck by the fact that, excepting for a slightly thickened fissure on the postero-anterior projection, the lung fields are quite clear and the hilar regions normal. In many of such instances, the lateral revealed unequivocal evidence of enlargement of the bronchial glands. In other instances, the enlarged glands plus the thickened fissure, can be clearly seen on the postero-anterior view. (Fig. 25).



<u>Fig. 25.</u> Radiograph showing enlarged glands at the right hilar region (enlarged bronchial glands) plus thickening of the lesser interlobar fissure. This combination suggests tuberculosis.

Cardiac disease is another fruitful cause of thickening of the fissure, including the lesser fissure. It is stated (Kerley, 1936) that the thickening in conditions like Mitral Stenosis is due to transudation 'into the large lymphatic which connects the superficial pulmonary plexus with the parietal pleura.'

Fig. 26 is the postero-anterior view of a chest of a patient with mitral stenosis (note the prominent pulmonic arch of the cardiac shadow) with thickening of the lesser fissure.

Fig. 26. Radiograph showing :-
(a) A mitralised heart due to mitral stenosis,
(b) Thickening of the lesser interlobar fissure.

(II) <u>The Lesser Interlobar Fissure as a Line of Demarcation.</u>

The lesser, and also the main interlobar fissures, are very important in consolidation in deciding which lobe of the lung is affected.

<u>In right upper lobe consolidation</u>, the lower border of the consolidated area is sharply outlined below by the lesser fissure on the postero-anterior view (Figs. 27 & 28). This knowledge enables the radiologist to determine with ease whether pneumonia is confined to the upper lobe. Any clouding below the lesser interlobar fissure must mean that the other lobes or lobe are also affected.

On the lateral view, the lesser fissure reveals the lower border of the consolidation equally well. It shows in addition that part of the outlining of the upper lobe consolidation is performed by the upper part of the main fissure.
Finally, it shows an obtuse angle, formed by the upper

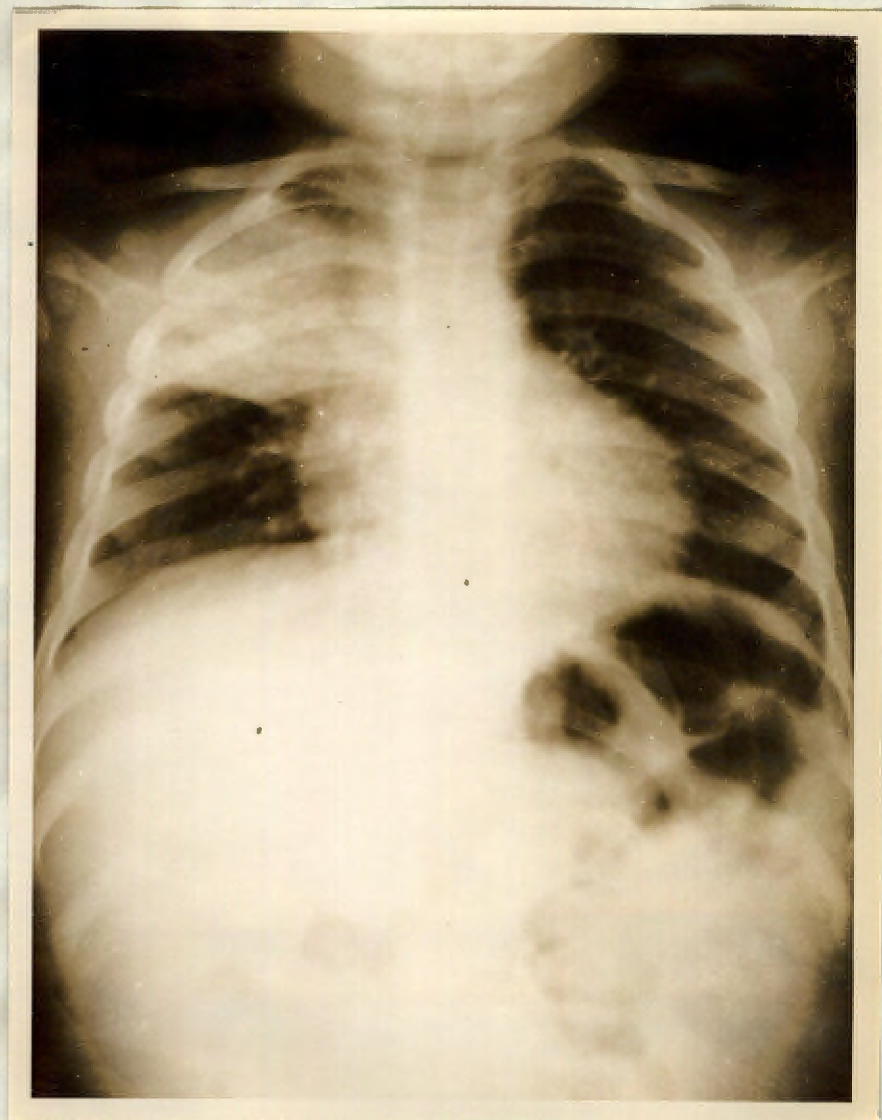
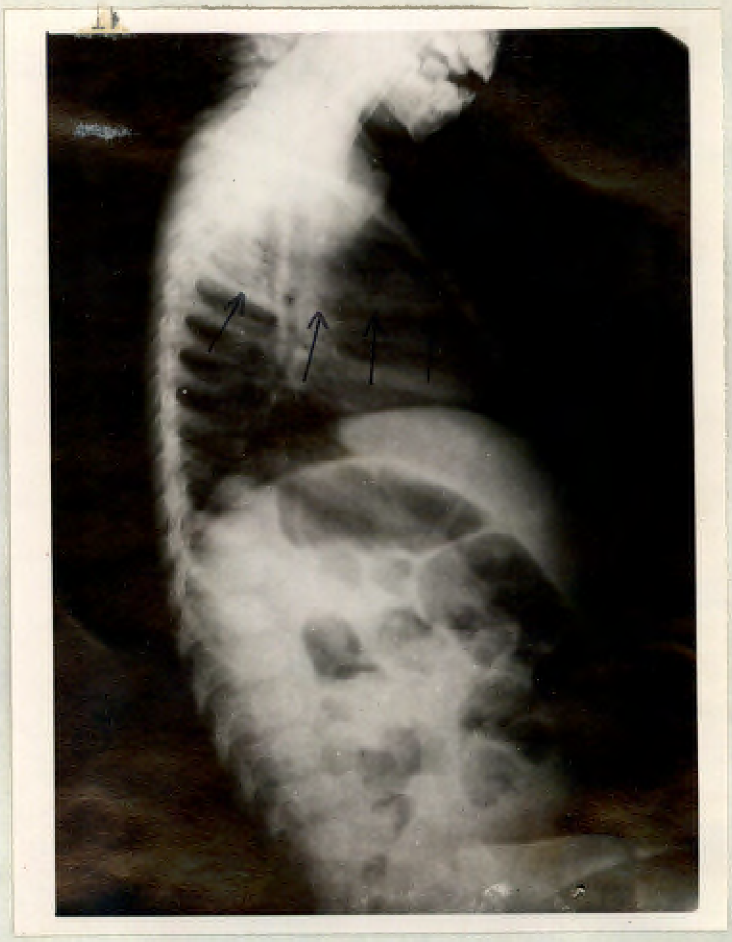
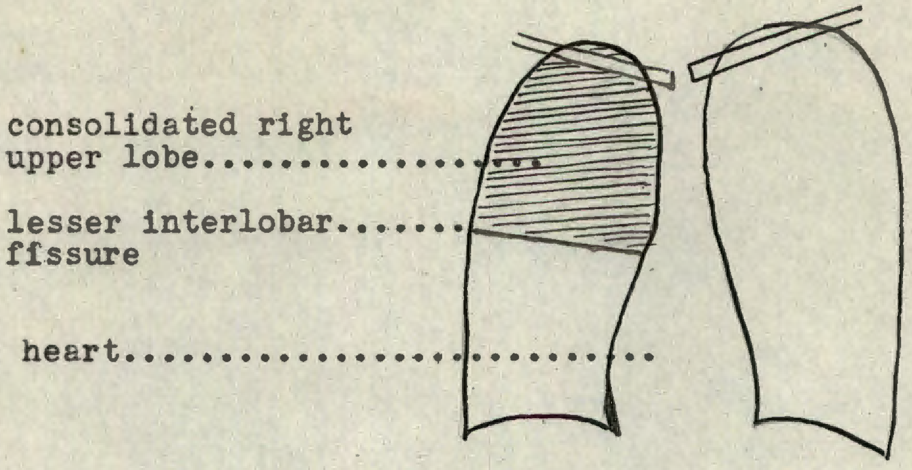


Fig. 27. Postero-anterior radiograph of a chest with consolidation of the right upper lobe, outlined below by the lesser fissure.

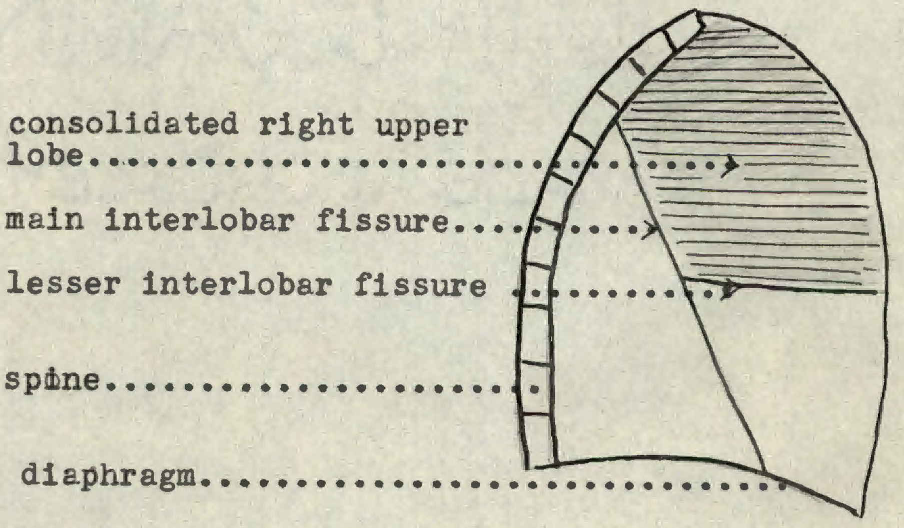


<u>Fig. 28.</u> Lateral radiograph of chest (same case as fig. 27) with consolidation of the right upper lobe. The upper part of the main fissure and whole length of the lesser fissure play a part in the delineation.

posterior portion of the lesser fissure, and filled up by the consolidated lung.

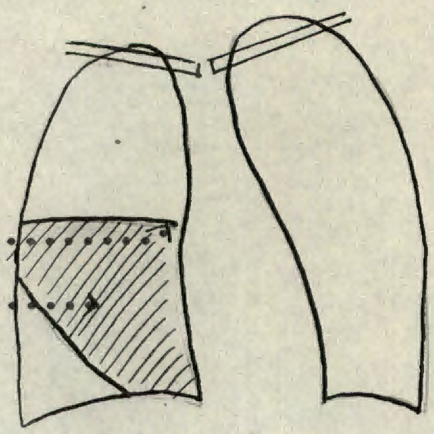


Schematic drawing of the chest in the postero-anterior projection showing the consolidated right upper lobe demarcated below by the lesser interlobar fissure.

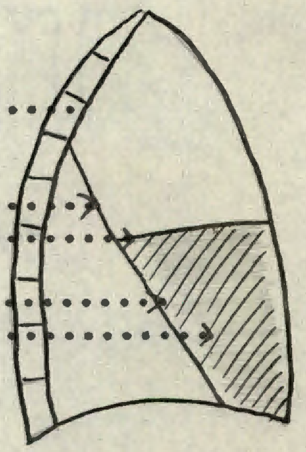


Schematic drawing of the chest in the lateral projection showing the consolidated right upper lobe and the part played by the lesser and the main fissure in the demarcation.

<u>In middle lobe consolidation</u>, the lesser fissure also plays an important part in the delineation.



<u>Schematic drawing of the chest in the postero-anterior projection showing the consolidated middle lobr demarcated above by the lesser fissure</u>.



<u>Schematic drawing of the chest in the lateral projection showing the consolidated middle lobe and the position of the fissures</u>.

On the postero-anterior view, there is, in middle lobe consolidation, an opacity at the basal region, which to the uninitiated looks like lower lobe consolidation. The lesser fissure affords the clue to the correct localisation, because it gives a straight upper border to the opacity. This is not the case in lower lobe consolidation. Clarity of the costo-phrenic angle is also a useful point in the differentiation. In addition to the drawings in the text, refer also to Fig. 29.

On the lateral view, the consolidated middle lobe, between the lesser fissure and the lower anterior portion of the main fissure, can usually be clearly visualised.

Lower lobe consolidation shows on the postero-anterior view as an opacity occupying about two-thirds of the lung field with an ill-defined upper border. The reason for this lies in the oblique inclination of the main fissure. This can be very easily understood by reference to the accompanying drawing (in the text) and the Figs. 30 & 31.

The density of the shadow increases from above downwards.

Fig. 29. Postero-anterior radiograph of a chest with typical consolidation of the right middle lobe. Note the sharp upper border, due to the lesser fissure. This differentiates it from lower lobe consolidation.

Fig. 30. Lower lobe consolidation on the postero-anterior view. Note that the upper border is ill-defined because of the obliquity of the main fissure. The lesser fissure plays no part in the delineation.

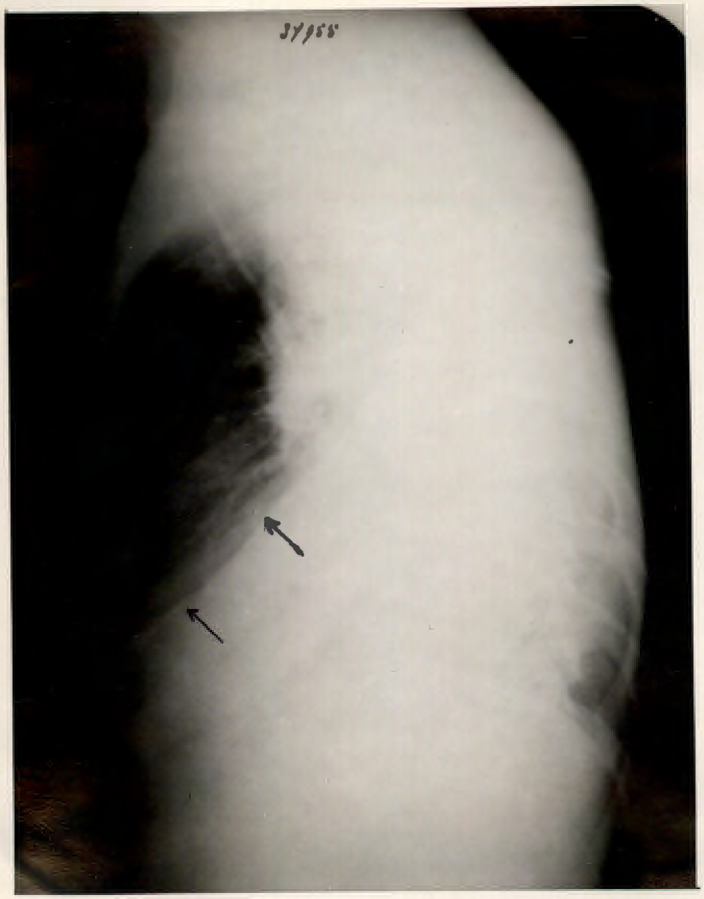
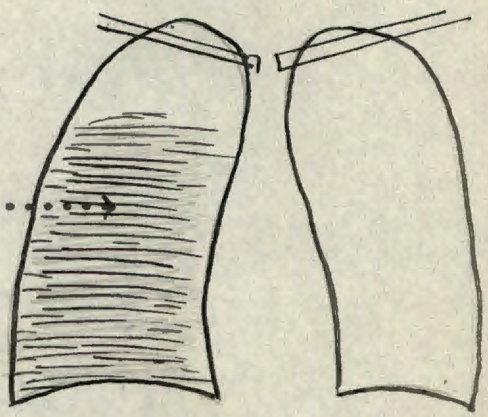
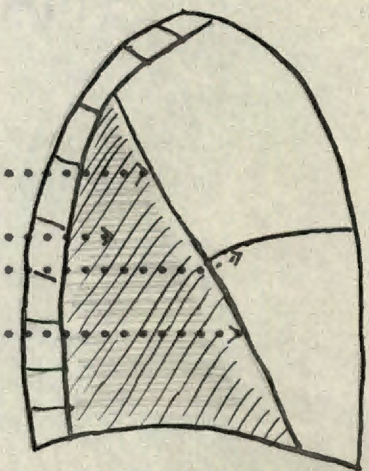


Fig. 31. Lateral view of chest in fig. 30, showing the posterior position of the consolidated lower lobe. The whole length of the main fissure takes part in the delineation.

The opacity is situated posteriorly on the lateral view, and delimited from the other lobes by the entire length of the main fissure. The value of the lesser fissure lies in the fact that it serves to differentiate lower from middle lobe consolidation in the postero-anterior view (referred to under middle lobe consolidation).



Schematic drawing of chest in postero-anterior view showing consolidated lower lobe and absence of sharp upper demarcation.
Costophrenic angle also clouded.



Schematic drawing of chest in the lateral view showing consolidated lower lobe and part played by the lesser and the main fissure.

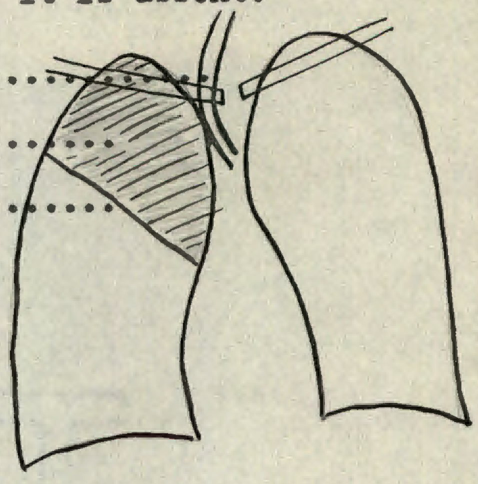
(III) Displacement of the Lesser Interlobar Fissure.

The fissure may be displaced to a marked or a slight extent.

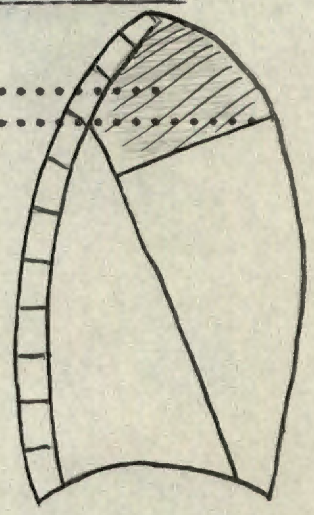
A. Marked Displacement of the Lesser Fissure.

I. Atelectasis.

In right upper lobe atelectasis, a triangular shadow is seen in the upper zone on the postero-anterior view. The lower border of this shadow, is the lesser interlobar fissure displaced upwards. The angle x is invariably greater than 105 degrees, i.e. the fissure is elevated more than 15 degrees above the horizontal. The elevation of the fissure helps in the differentiation between upper lobe atelectasis and upper lobe consolidation. The postero-anterior view is usually the more valuable of the two views as it also shows the mediastinal displacement and narrowing of the intercostal spaces, which are usual accompaniments of atelectasis. The displacement of organs is also helpful in the differentiation between atelectasis and consolidation, as in the latter, it is absent.



Drawing of a chest in the postero-anterior projection showing triangular upper zone opacity, upwards displacement of the lesser fissure and displacement of organs.



Lateral of the above showing position of the atelectatic lobe and elevation of the fissure (lesser).

The author of this thesis has observed that the medial portion of the lesser interlobar fissure does not rise appreabove its normal position (discussed previously and found to be approximately 12 mm. from lowest portion of the anterior end of the third rib).

Fig. 32 indicates amrked atelectasis of the right upper lobe (proven case of bronchial carcinoma).

In <u>middle lobe atelectasis</u> a shadow of varying density is seen on the postero-anterior view, at the middle zone, close to the right border of the heart. On the lateral view, the atelectatic lobe can be seen anteriorly between the depressed lesser fissure and the lower portion of the main fissure. The diagram in the text, is an attempt to explain the usual radiographic appearances. Reference should also be made to Fig. 33.

It is sometimes very difficult to distinguish between an atelectatic middle lobe, a consolidated middle lobe and an interlobar empyema. In most instances of lobar atelectasis, there is usually in addition to the features mentioned above, also displacement of the heart and mediastinum towards the affected side.

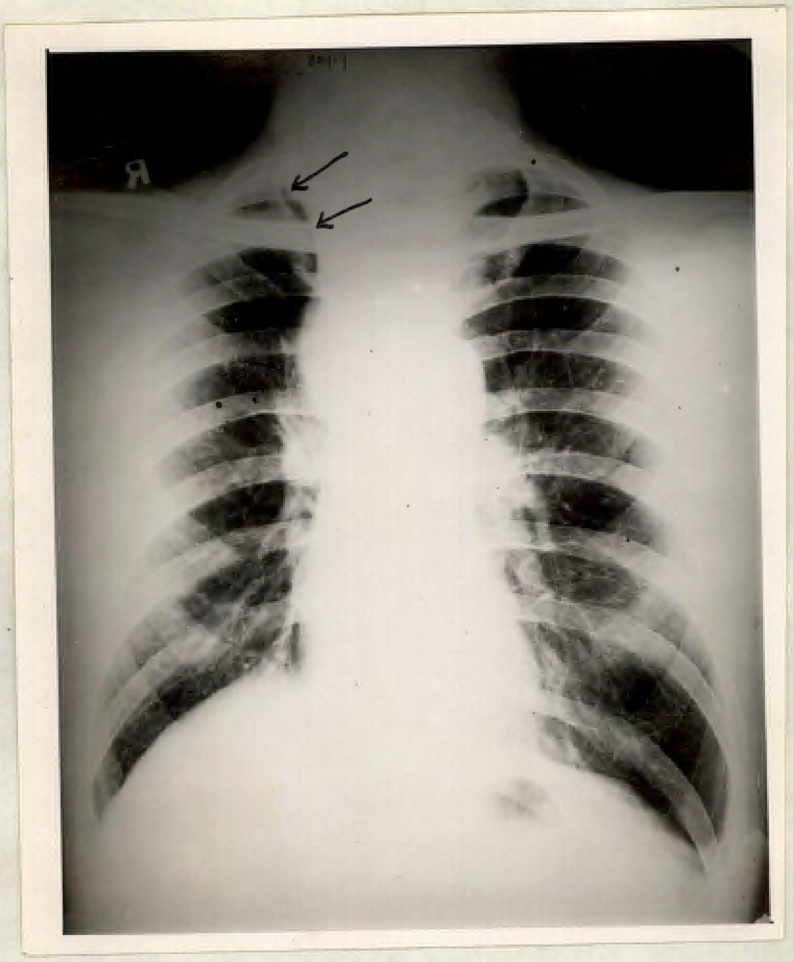


Fig. 32. Postero-anterior radiograph showing an atelectatic right upper lobe lying very close to the vertebral shadow. This was a provéd case of bronchial carcinoma.

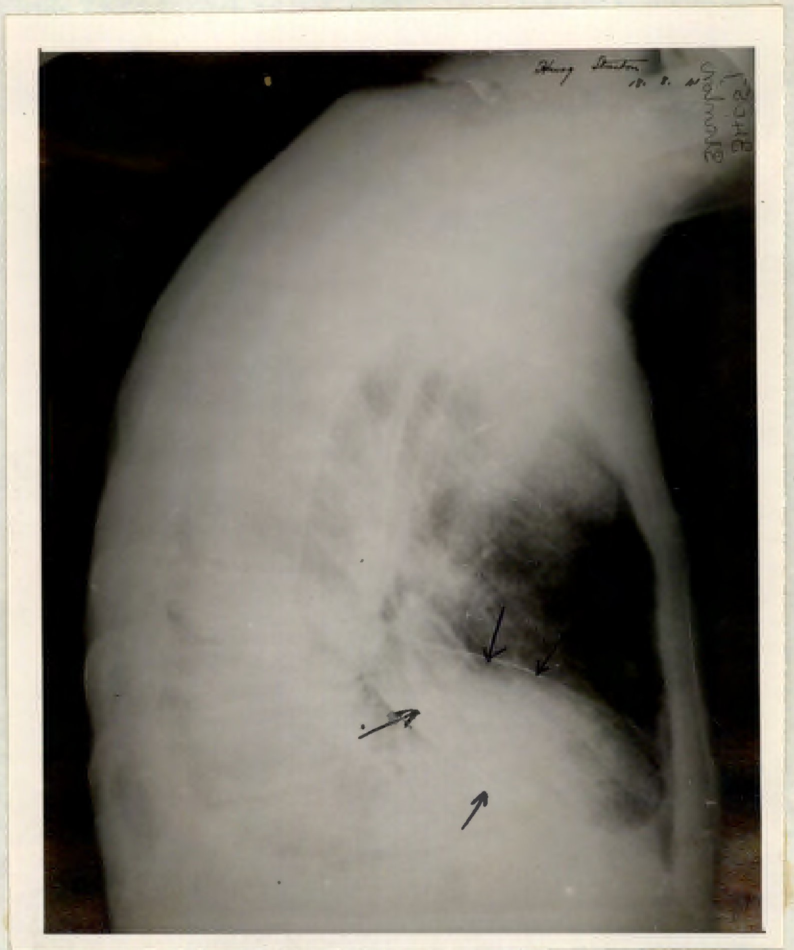


Fig. 33. Lateral radiograph of a right lung. In addition to consolidation of the middle lobe, the depressed fissure shows the presence of an element of collapse as well. There is also a little fluid at the base.

This often helps in the differential diagnosis between these conditions.

atelectatic middle lobe....................

cardiac displacement to the right........................

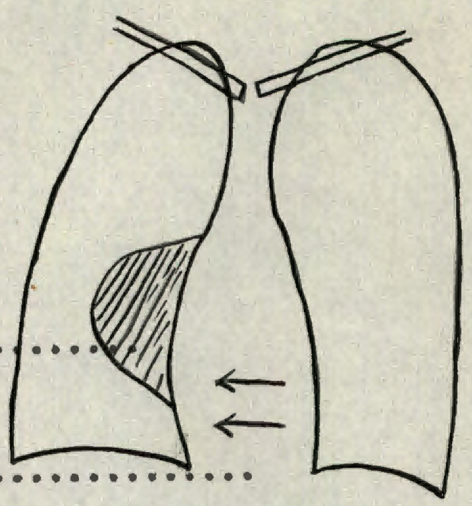


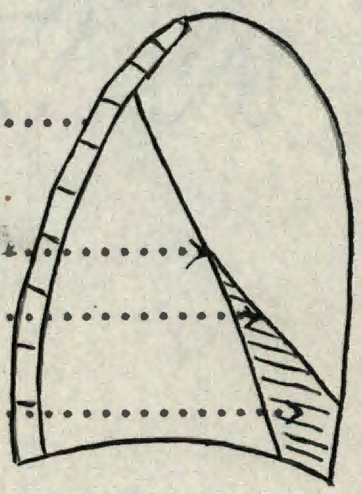
Diagram to show position of the atelectatic middle lobe on the postero-anterior view.

spine..................

main fissure....................

lesser fissure..................

atelectatic middle lobe........................



Lateral of the above showing the position of the atelectatic middle lobe compressed between the main and the lesser fissures.

In <u>right lower lobe atelectasis</u>, a dense triangular opacity appears in the right cardiophrenic angle region on the postero-anterior view of the chest. On the lateral view, or better still the left oblique view, this opacity is situated well posteriorly in the region of the posterior diaphragmatic cul-de-sac. The anterior, oblique border, is composed of the main interlobar fissure. If the atelectasis is complete, the shrunken lobe obviously must occupy a smaller space in the thorax than the normal one, and this must then be associated with an alteration in the relative positions of the fissures. The main fissure is displaced backwards, as shown by the lateral view, while this same view shows the posterior part of the lesser fissure lower in position than the anterior.

On the postero-anterior view, the lesser fissure, having assumed a more oblique plane to the direction of the rays, is no longer projected as a thin line in the mid-zone of the right lung. (See Fig. 34 a.)

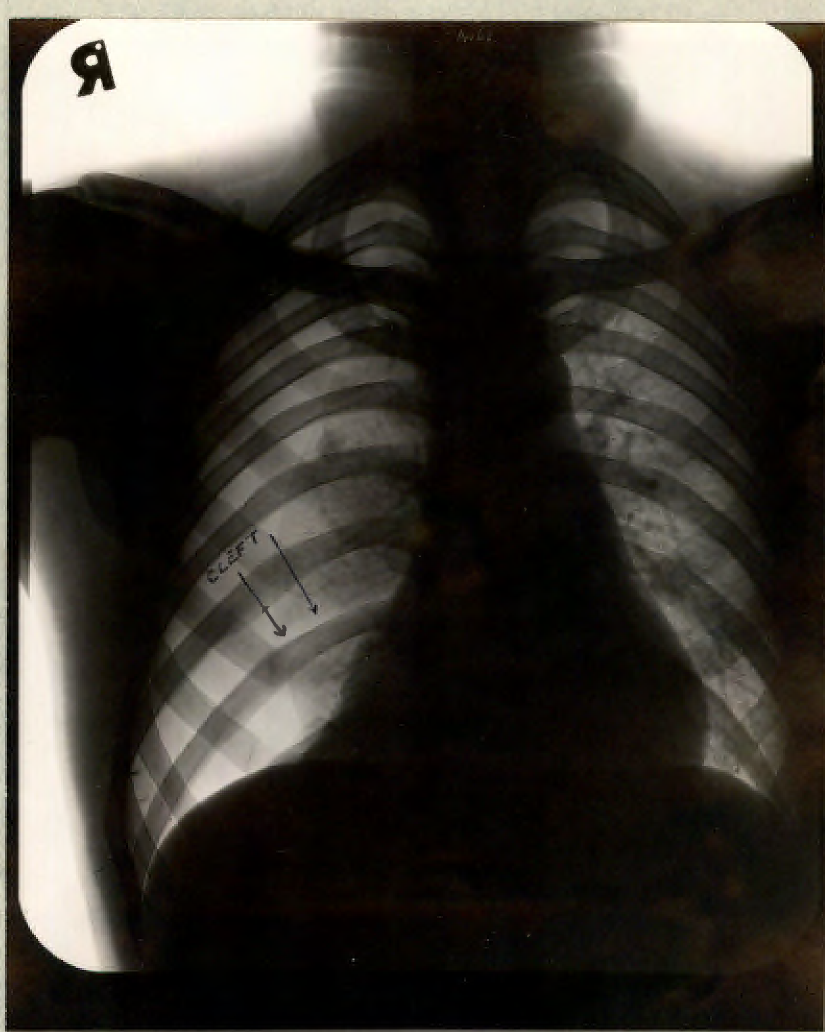
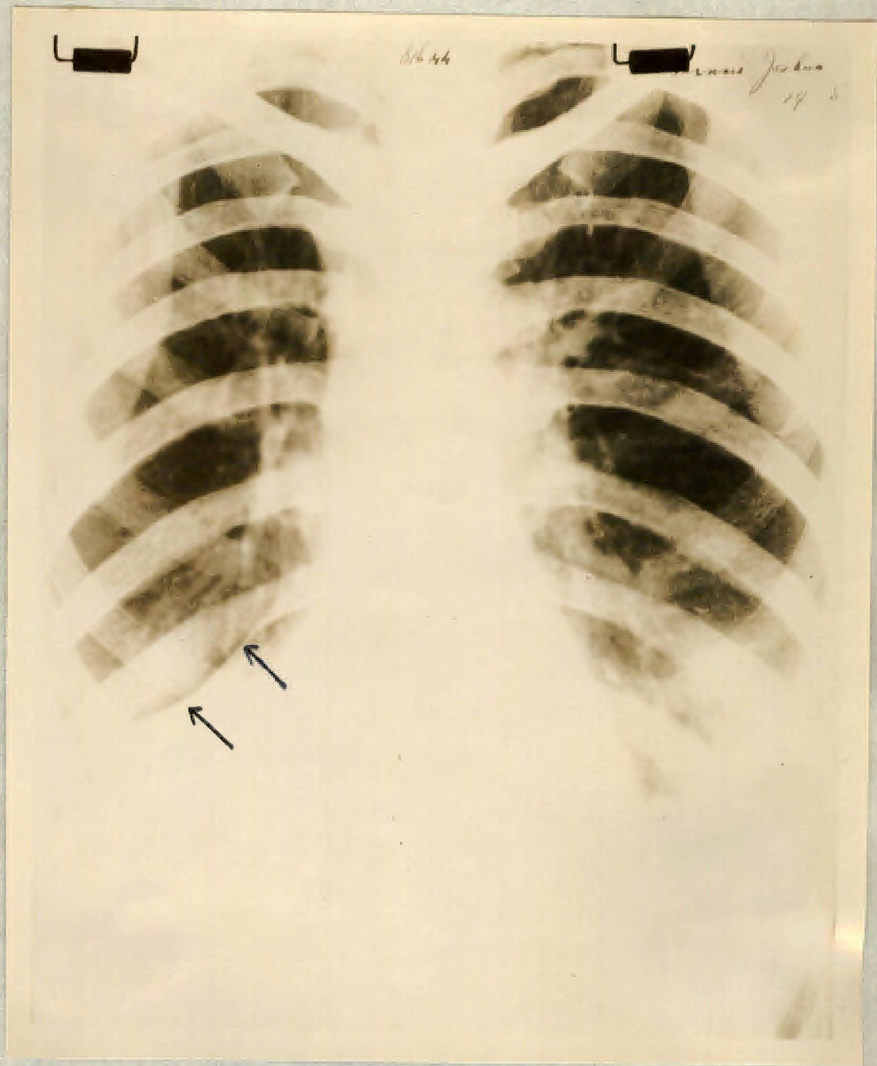


Fig. 34, a. Postero-anterior view showing right sided pneumothorax with massive atelectasis of the right lower lobe (triangular shadow in the cardiophrenic angle). Note that the the lesser fissure does not show as a thin hair line because of obliquity of the cleft between the upper and middle lobes, which is brought about by the atelectasis of the lower lobe.

Fig. 34, b. Lateral view of the same chest with the right sided pneumothorax. The lesser fissure is clearly visible on this view (not on the P.A. view).

Fig. 34, c. Postero-anterior view of the same chest after some re-expansion of all the lobes. Note how the lesser fissure now becomes visible as a line between the upper and middle lobes. Note also the decrease in the angle x.



<u>Fig. 34, d.</u> Postero-anterior view of a chest with complete atelectasis of the right lower lobe.
Note the dense triangular shadow in the right cardio-phrenic angle and the absence of a demonstrable lesser fissure.
(Note inflammatory changes at the left base).

This Fig.34, a. is the postero- anterior view of the chest of a patient after the induction of a pneumothorax. There is a typical atelectatic right lower lobe and there is selective collapse of the other two lobes in all zones.

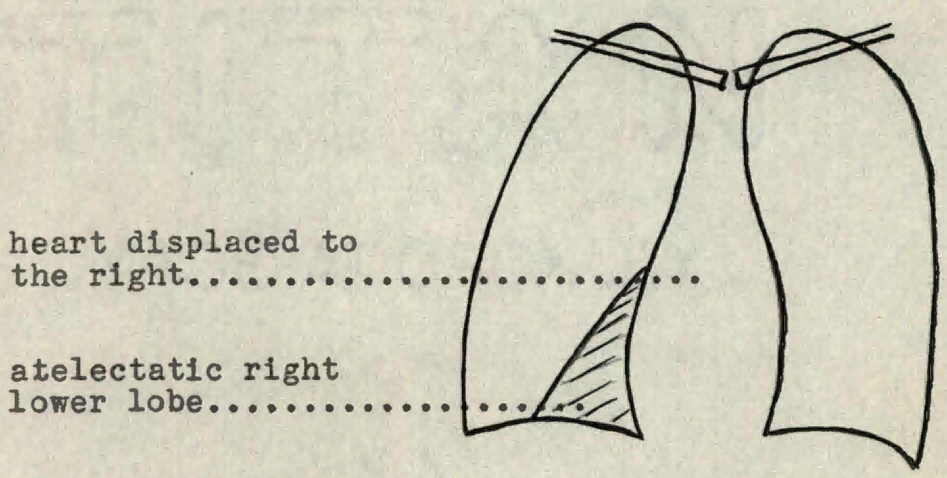
It becomes clear that the outer border of the atelectatic lower lobe is not formed by the lesser fissure, but that the latter shows as an oblique cleft between the upper and the middle lobes slightly higher up. This obliquity explains why the lesser fissure is not visible on the postero-anterior view in cases of complete atelectasis of the right lower lobe.

Note also in this view the downward lateral inclination of the above-mentioned cleft with consequent decrease in the angle it forms with the vertical on the medial aspect.

The lateral view (Fig. 34, b.) clearly shows the lesser fissure.

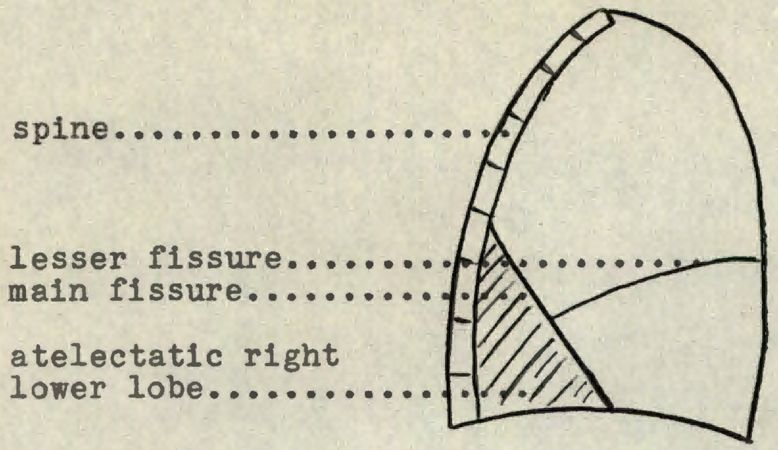
A subsequent postero-anterior view (Fig. 34, c.) shows some re-expansion of all the lobes. Note how the lesser fissure becomes visible as the relative normal positions of the various lobes are once more approached.

If the right lower lobe is, however, only partially atelectatic, the lesser fissure is still visible and is displaced downwards with the angle "x" slightly below the normal. (Refer again to Fig. 34,c.)



<u>Triangular shadow of the atelectatic right lower lobe at the right cardiophrenic angle.
In complete atelectasis of the right lower lobe, the lesser fissure assumes an oblique position and does not show as a 'hair line' on the skiagram.</u>

(Please turn over for lateral.



Lateral of the diagram on the previous page showing the position of the atelectatic lower lobe and the oblique inclination of the lesser fissure (the latter inclination demonstrates why the lesser fissure is not usually visible on the P.A. view in cases with atelectatic lower lobes.

2. Fibrosis.

Fibrosis can also produce marked alteration in the position of the lesser fissure. It is, for example, often noticed that the lesser fissure is displaced upwards in cases of tubercle, which has healed with fibrosis, and downwards in cases with fibrotic basal changes. In addition to a decrease in the angle x below 80 degrees, in basal fibrosis, and an increase above fibrosis, the fissure is usually distorted, for obvious reasons. An elevated, distorted lesser interlobar fissure may be the only residual evidence of healed upper zone inflammatory lesions (e.g. tubercle).

There is a belief prevalant amongst many that fibrosis usually shows on the roentgenogram as linear streaks or lines. Vascular or bronchial striations are thus often mistaken for fibrotic changes. Kerley (1936) remarked that great harm is done by doctors in mistaking normal pulmonary markings for fibrosis.

I would like to suggest that traction on the heart, big blood-vessels, trachea and mediastinum, plus abnormal position and distortion of the fissure, should be regarded as very important radiographic evidence of fibrosis, even in the absence of 'linear streaks of fibrosis'.

3. Space- occupying lesions.

(a) Fluid conditions.

An encysted effusion, can displace the lesser interlobar fissure downwards, if situated in the upper part of the lung field. This is often a very important point in the differential diagnosis of shadows occupying the upper zone of the lung.

Further, it is a wellknown rule that bulging of a fissure in the neighbourhood of a pneumonic process, must always be regarded as very suspicious of the development of interlobar fluid.

(b) <u>Solid conditions.</u>

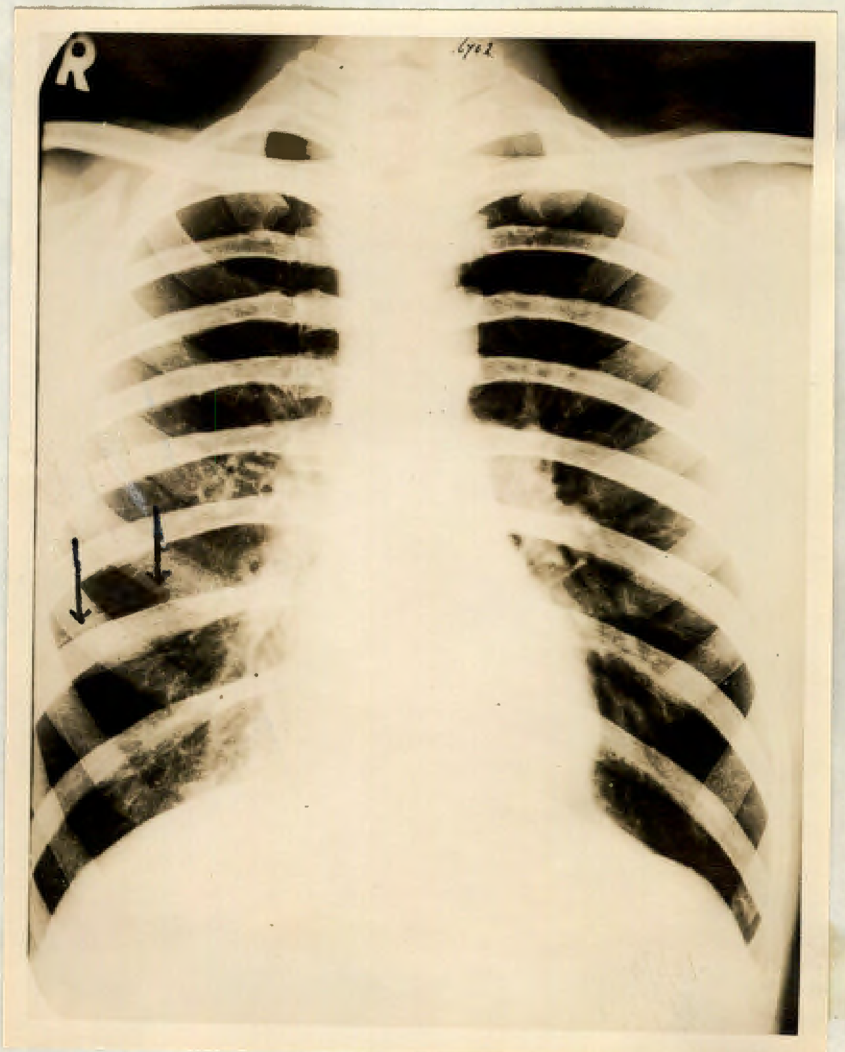
Solid lung tumours, whether benign or malignant, lung abscesses and hydatids, may all displace the fissure by virtue of their proximity to it.

B. Slight displacement of the Lesser Fissure.

1. Bronchiectasis.

I have often come across chest radiographs where there is slight depression of the lesser with diminution of the angle x below 80 degrees. Apart from this observation, nothing else of note has been visible on the plate with special reference to the base. Many of these cases showed bronchiectatic changes at the base, after bronchography.

Fig. 35 is the postero-anterior view of the chest of a patient after resolution of bilateral basal pneumonia. During the period of resolution, a down-ward tilted lesser fissure became obvious. The final straight X-ray (Fig. 35) showed only slight increase in the broncho-vascular striations, such as is usually seen after resolution of inflammatory lung lesions, with slight, even depression of the lesser fissure, the angle x being less than 80 degrees. Bronchogram (Fig. 36) revealed unmistakable of basal bronchiectasis.



<u>Fig. 35.</u> Radiograph of a chest showing slight depression of the lesser fissure. Nothing else of note is seen apart from slight increase in the broncho-vascular striations at the right base, as is customary after a pneumonia or pneumonitis.

Fig. 36. Bronchogram of the same patient as in fig. 35, showing unmistakable evidence of bronchiectasis.

Fig. 37. is the postero-anterior view of the chest of a young woman with clinical symptomatology very suggestive of bronchiectasis, but with nothing abnormal on the straight X-ray, except a downward-tilted lesser fissure, the angle x being less than 80 degrees. Subsequent bronchography revealed evidence of basal bronchiectasis(Fig. 38).

That atelectasis plays an important role in the production of bronchiectasis, is now generally accepted.

Lee Lander and Davidson (1938) emphasized the importance of pulmonary atelectasis in the causation of bronchiectasis. This was shown by bronchographic studies of atelectatic lobes, and experimentally in animals.

Fleischner (1941) stated : 'Atelectasis appearing with bronchostenosis or associated with inflammatory bronchial or pulmonary processes plays a decisive role in the formation of bronchiectasis.'

Both Lander and Davidson and Fleischner (1938 and 1941 respectively), maintain that there need not be any destructive changes in the

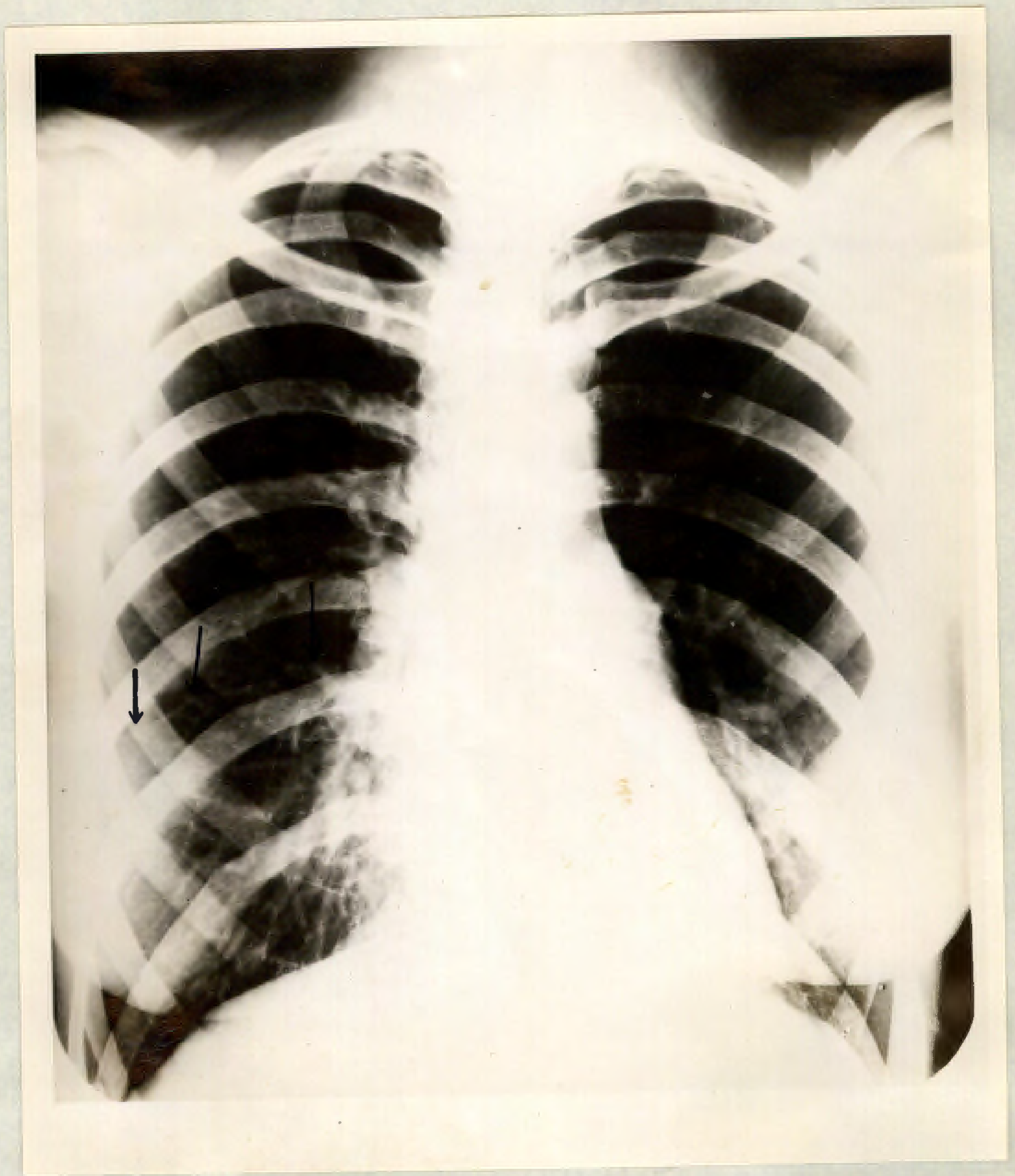


Fig. 37. Postero-anterior view of the chest of a woman with a clinical symptomatology suggestive of bronchiectasis. Nothing abnormal is seen apart from depression of the lesser fissure below an angle of 80 degrees.

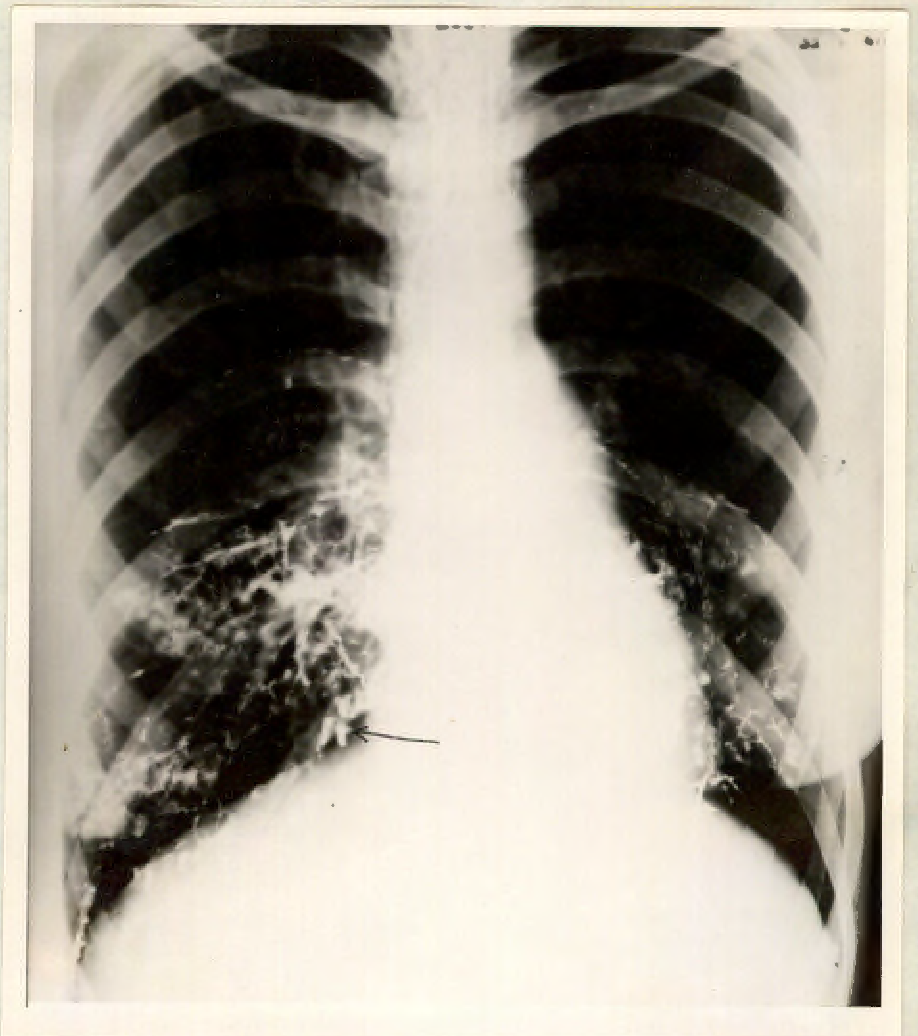


Fig. 38. Bronchogram of the same patient as in fig. 37, showing bronchiectasis.

bronchial wall, and that the traditional view that infection is primarily responsible for the formation of bronchiectasis, is no longer acceptable. Flesichner (1941) has found, that a study of resected lobes (after lobectomy) showed 'only moderate inflammatory changes in the parenchyma, the bronchi being dilated but their walls thin and their mucosa delicate.'

Returning to my own cases woth the depression of the fissure, as the only radiological manifestation of possible pathology, the question naturally arises as to the possible cause of the depression. The absence of any appreciable distortion of the depressed fissure, seems to suggest that the appearances could be explained best on a basis of partial atelectasis, as fibrotic changes are likely to produce distortion.

The importance of the observation does not lie os much in the fact that it is in agreement with the view that atelectasis plays an important role in the production of bronchiectasis.

<u>The importance is in the fact that depression of the fissure, with decrease in the angle x below 80 degrees, must be regarded as very suspicious of basal pathology</u>, even in the complete absence of increased basal striations, "tramline" effects, thickened bronchi or other of the usual suspicious features.

2. <u>Emphysema.</u>

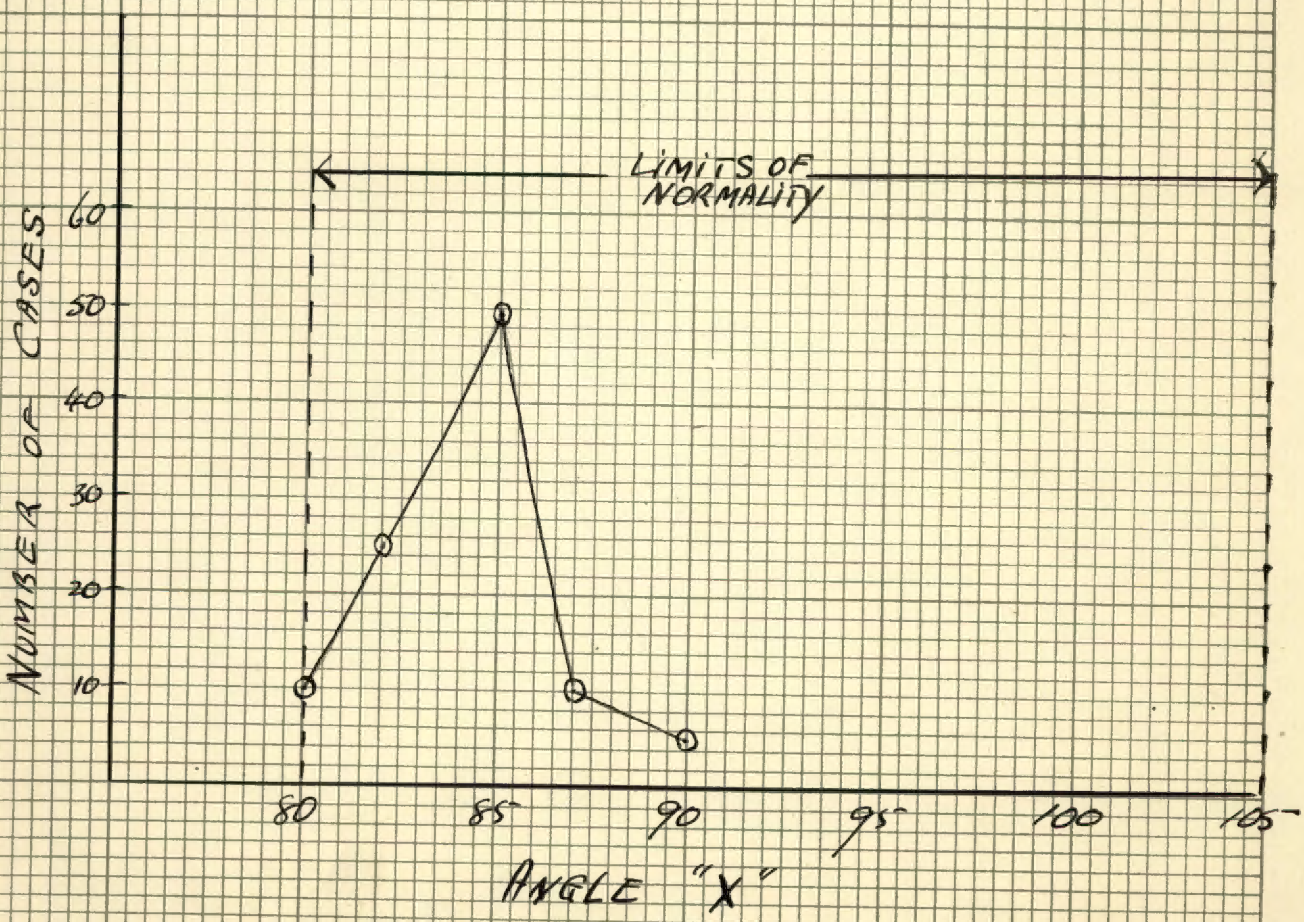
In 100 unselected cases of emphysema, in which the fissure was visible, I have found that the lesser fissure was almost invariably slightly depressed, with the angle of inclination (x) tending towards the lowest limits of normality.

50% of the xases showed the angle to be 85 degrees,
25% of the cases showed the angle to be 82 " ,
10% of the cases showed the angle to be 80 " ,
10% of the cases showed the angle to be 87 " ,
5% of the cases showed the angle to be 90 " ,

(Refer to accompanying graph. (Fig. 39).

In emphysema, the transverse and antero-posterior diameters of the thorax are increased, with the ribs more transversely situated and the diaphragm flattened and low in position.

FIG. 39.


LIMITS OF NORMALITY
NUMBER OF CASES
60
50
40
30
20
10
80
85
90
95
100
105
ANGLE "X"

There is very often associated kyphosis as well. The whole shape of the thorax is thus altered, and this alteration accounts for the change in position of the lesser fissure.

SUMMARY.

(1) Features of the anatomy of the fissures and the lobes of the lungs are presented from a study of these structures in both the living subject and in the removed lung.

(2) A detailed investigation of the lesser fissure in 400 normal cases was undertaken. This established the criteria for the recognition of the normal lesser interlobar fissure.

(3) A study of the azygos vein lobe fissure in the same cases permitted a description of the features by which this structure may be recognized.

(4) A similar study was performed in the case of the true azygos lobe fissure.

(5) On the basis of these and other studies, a scheme of differential diagnosis of the lesser interlobar fissure from other

causes of "hair-lines" has been compiled.

(6) The application of the knowledge gained of the radiological anatomy of the lesser fissure is discussed.

(7) The lesser fissure acts as a guide to diagnosis in three main ways :-

(a) It may show thickening.
(b) It may show displacement.
(c) It acts as a line of demarcation.

Illustrative examples are discussed.

(8) Some of the more important conclusions reached are given below.

(a) Thickening of the lesser fissure plus enlarged bronchial glands in childhood are highly suggestive of tuberculous infection.
(b) Displacements of the lesser fissure are of the utmost importance in the diagnosis of atelectasis of the various lobes of the right lung.
(c) Fibrosis usually produced distortion in addition to displacement of the lesser interlobar fissure. This plus traction on the heart, big blood vessels, trachea and media-

stinum should be regarded as very important radiographic evidence of fibrosis.

(d) Downward tilting of the lesser interlobar fissure to a degree greater than normal, without any other abnormal signs on X-ray is highly suspicious of basal pathology such as bronchiectasis.

(9) 100 cases of emphysema were studied. The lesser interlobar fissure was depressed in all to a degree near the outermost limits of normality.

Owing to difficulties in obtaining photographic materials, it has been necessary to replace certain of the photographs by black and white diagrams.

GENERAL SUMMARY.

General Summary.

The individual summaries are reproduced here together for ease of reference.

(1) A brief historical review is presented of the interrelationship between the heart and lungs.

(2) Methods of studying the lungs are outlined and the advantages and disadvantages of the various procedures are discussed.

(3) Attention is drawn to the methods and value of studying lungs removed from the body.

(4) The bronchial tree of the right lung has been investigated in the living subject.

(5) The applications of the study in cases of bronchiectasis and of bronchial occlusion due to various causes, is discussed.

(6) The bronchial tree has also been studied by means of radiographs of lungs removed from the body both at autopsy and in the anatomy dissecting room.

(7) Methods are described for rendering the bronchial tree in these lung radio-opaque.

(8) From these studies on both the removed lungs and the living subject, it is concluded that the bronchi divide

chiefly in a monopodial manner. The finding is in agreement with Aeby and contrary to Ewart.

(9) It is maintained, in agreement with Twining, that exact anatomical knowledge of the bronchial tree is of importance in radiological interpretation.

(10) A method of injecting the terminal subdivisions of the bronchi and demonstrating them radiologically is described.

(11) The detailed anatomy shown in this way confirms the findings of previous histological studies.

(12) Attention is drawn to the study of the pulmonary arterial tree in the living subject by Moniz.

(13) Methods of injecting contrast media into the arterial tree of the removed lung are described.

(14) Lungs studied radiographically after this preparation show the intrapulmonary anatomical relationship to be as demonstrated two and a half centuries ago, by Cowper.

(15) The diameters of the bronchi and the pulmonary artery branches were measured at corresponding distances from their commencement. It was found that at all points, right down to the finest subdivisions visualised, the bronchi and the pulmonary arteries are more or less equal in size to one another. This refutes Miller's suggestion that the arteries diminish in size much more

rapidly than the bronchi, and that the smallest divisions of the arteries are only one fourth to one fifth of the diameter of the bronchi.

(16) The mode of division of the arteries is described. It is mainly dichotomous in type.

(17) Attention is drawn to the difference in the modes of division of arteries (dichotomous) and bronchi (monopodial), as revealed by the present studies.

(18) It is pointed out that the anatomical features described in the present work are of the utmost importance in the early recognition of pathology in the bronchi and in the interpretation of the straight radiograph. Bronchi that are visible on a straight radiograph are pathological. Hence, if a shadow can be identified as bronchial and not arterial, then pathology must exist in those bronchi. The anatomical features described, i.e. that there is a definite difference in the mode of division between arteries and bronchi, enable the distinction to be made.

(19) The lungs of the bodies preserved by formalin and injected with starch and vermillion for anatomy dissection were found to be suitable for radiological investigation of the pulmonary venous tree without further preparation.

(20) If lungs are removed from the body and fixed in formalin for a few days, it is impossible to inject the pulmonary vascular trees.

(21) The explanation probably lies in the fact that the lung preserved inside the body is protected from atmospheric pressure.

(22) The investigation suggests that this feature may help to explain why the intra-vitam method of fixation of tissues, is the most satisfactory.

(23) Features of the anatomy of the fissures and the lobes of the lungs are presented from a study of these structures in both the living subject and the removed lung.

(24) A detailed investigation of the lesser fissure in 400 normal cases was undertaken. This established the criteria for the recognition of the normal lesser interlobar fissure.

(25) A study of the Azygos vein lobe fissure in the same cases permitted a description of the features by which this structure may be recognised.

(26) A similar study was perfomred in the case of the true Azygos lobe fissure.

(27) On the basis of these and other studies, a scheme of differential diagnosis of the lesser interlobar fissure from other causes of 'hair-line' has been compiled.

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(c) Fibrosis usually produces distortion in addition to displacement of the lesser interlobar fissure. This plus traction on the heart, big blood vessels, trachea and mediastinum should be regarded as very important radiographic evidence of fibrosis.

(d) Downward tilting of the lesser interlobar fissure to a degree greater than normal, without any other abnormal signs on X-ray is highly suspicious of basal pathology such as bronchiectasis.

(31) 100 cases of emphysema (showing the lesser fissure) were studied. The lesser interlobar fissure was depressed in all to a degree near the outermost limits of normality.

ACKNOWLEDGEMENTS.

Acknowledgements.

I wish to thank Professor M.R. Drennan for facilities extended to me in his laboratory.

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